The Residential Energy Map: Catalyzing Energy Efficiency Through Remote Energy Assessments and Improved Data Access

By

Alexis Howland

BA in Economics
Brown University
Providence, Rhode Island (2008)

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Author ______________________________
Department of Urban Studies and Planning
May 22, 2013

Certified by ______________________________
Lecturer Harvey Michaels
Department of Urban Studies and Planning
Thesis Supervisor

Accepted by ______________________________
Associate Professor P. Christopher Zegras
Chair, MCP Committee
Department of Urban Studies and Planning

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Abstract

Although energy efficiency has potential to be a significant energy resource in the United States, many energy efficiency projects continue to go unrealized. This is especially true in the residential sector, where efficiency programs, frequently administered by utilities, see very low participation rates. However, growing access to data and the growing prevalence of mapping technologies provide new avenues for introducing energy performance information in ways that could encourage increased energy efficiency implementation. Renters and homebuyers are increasingly using online interactive maps to inform their housing choices. If energy data is mapped or incorporated into an existing real estate map, energy efficiency could become a valued asset that influences housing decisions and encourages building upgrades by property owners. However, major obstacles remain in accessing the data necessary to create meaningful energy maps. Privacy is the most significant barrier to displaying building-level energy consumption and performance information.

This thesis explores how an energy map could catalyze energy efficiency upgrades, specifically in the residential market. This research examines existing energy maps, existing energy assessment platforms and what data they use, and evaluates the state of energy data access in the United States. It seeks to answer what data is necessary to map building level energy performance, what policies are necessary to access that data, and how should energy information be displayed in a map for the most meaningful impact.

This research suggests that State mandates may be necessary to access individual residential building energy data; that the Federal government should recommended a standardized platform, such as the Standard Energy Efficiency Data platform, to create a national standard for storing energy data and data taxonomy; and that an energy map will be most effective when displaying a relative energy performance score which could possibly be calculated from energy data and other publicly available building records.

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I would like to thank the numerous people who talked to me about energy, maps, and data along the way. I would like to thank the wonderful people who agreed to participate in interviews. I would also like to thank friends and family who patiently listened to my ramblings. Especially my friends at DUSP who helped me to stay on track and finish my work!

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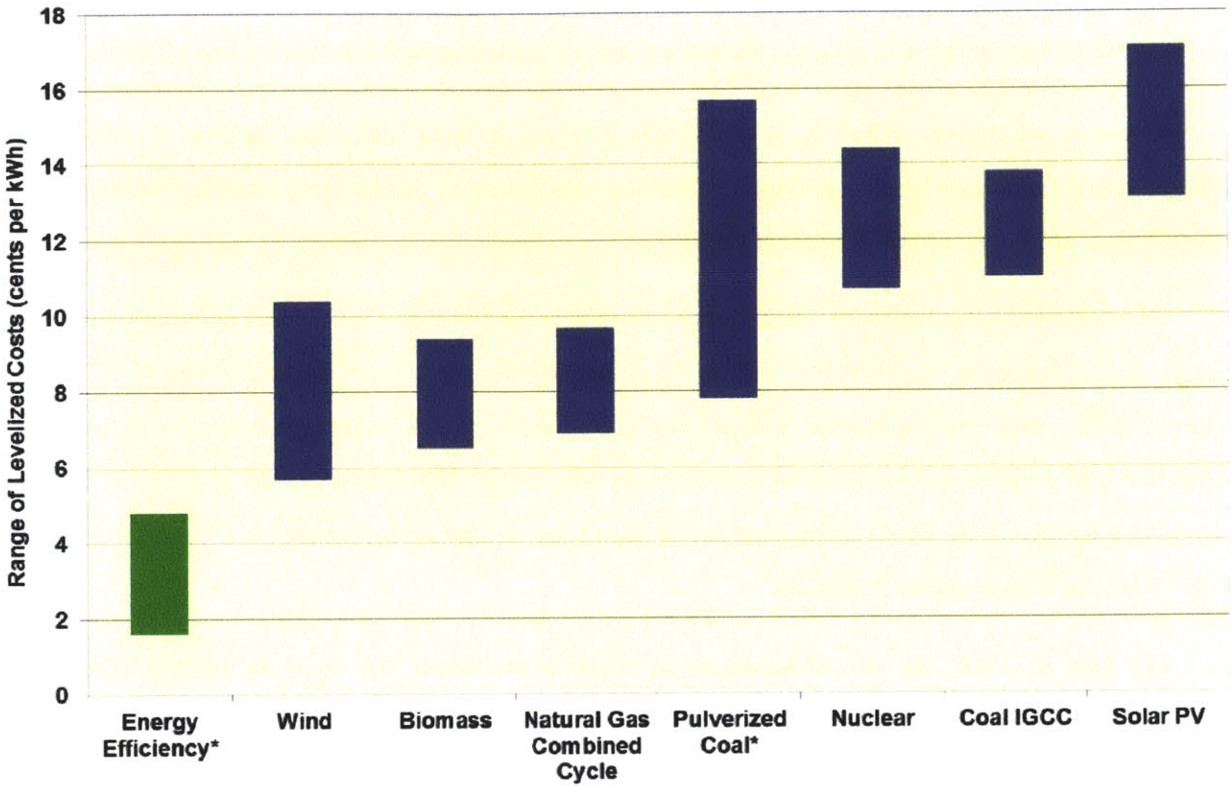
Chapter 1 – Introduction

On May 9, 2013, a new milestone was reached – for the first time in recorded history, carbon dioxide concentrations in the atmosphere exceeded 400 parts per million, as measured atop the Mauna Loa volcano in Hawaii (Vastag & Samenow, 2013). The last time concentrations were this high was over 3 million years ago (Vastag & Samenow, 2013). Climate scientists such as NASA's Dr. James Hansen have stated that 350 ppm of CO_2 is the highest concentration that would not produce dramatic and unpredictable changes in climate patterns (Merchant, 2013). An international consortium of nations has agreed that carbon dioxide concentrations should not be allowed to exceed 450 ppm, a number which is connected to a 2-degree Celsius increase in global temperatures (Biello, 2013). Reaching 400 ppm this May is significant – CO_2 concentrations will definitely continue to rise and this means we need to aggressively find ways to reduce dependence on carbon-based fuels.

Energy efficiency is one method of reducing carbon dependence. Using less energy in our buildings while still getting the same services from them is an optimal solution. And energy efficiency technologies are far cheaper to implement than other green energy sources like wind and solar. As seen in Figure 1, the levelized cost to utilities for energy efficiency is significantly lower than any other new energy source. The cost to utilities of energy efficiency usually includes program administration as well as whatever rebates or incentives they offer customers for implementing efficiency technologies. These total costs of energy efficiency prove to be cheaper per kilowatt-hour than for bringing online new sources of wind, solar, coal, natural gas, or nuclear energy.

Yet energy efficiency garners less attention and less support than solar or wind energy projects. A 2009 energy efficiency report by McKinsey estimated that it would be possible to reduce 2008 energy consumptions levels by 23% by 2020 using current net present value-positive energy efficiency technologies (McKinsey Global Energy and Materials, 2009). However, many of these energy efficiency opportunities go unrealized because of structural barriers and lack of knowledge.



*Notes: Energy efficiency average program portfolio data from Molina 2013 (ACEEE); All other data from Lazard 2012. High-end range of advanced pulverized coal includes 90% carbon capture and compression.

Figure 1 - Levelized Utility Cost of New Energy Resources (Elliott, 2013). This chart was developed for testimony in Ohio, but the general trend of energy efficiency being less expensive than other new energy sources is true across the country.

Furthermore, within energy efficiency opportunities, residential buildings are commonly overlooked. Low-hanging fruit tend to be commercial and industrial buildings where utilities can focus on a few big properties owned by only a few entities, and see major returns on their investments. However, McKinsey found that residential buildings account for 35% of end-use energy efficiency potential and 33% of primary energy potential (McKinsey Global Energy and Materials, 2009). This is a significant sector which should not be ignored. The residential market is challenging to reach for many reasons, including:

- The sheer quantity of individual buildings and individual owners requires sophisticated marketing and outreach campaigns.
- The audit and retrofit process can be time intensive and require multiple interactions with the utility and contractors. This can discourage some property owners who drop out.

- Energy use and cost are difficult for residential owners and occupants to understand. It's hard to "see" energy use and energy efficiency potential and to access energy use information.

There is no magic bullet to dramatically improve energy efficiency uptake in residential buildings; there will need to be outreach, financing, process, and information improvements across many different areas to overcome existing barriers.

Currently though, there are cities seeking to overcome the information and knowledge barrier. Fourteen U.S. cities have implemented energy disclosure and/or benchmarking requirements (Cluett & Amann, 2013). The basic premise behind disclosure laws is that exposing energy consumption information will lead to increased energy efficiency technology adoption possibly through improved property buying decisions, establishing new social norms for energy performance, or through mandated benchmarking and improvement indexes.

On May 8, 2013, Boston, Massachusetts became the latest city to implement a mandated energy disclosure policy. Like many other disclosure policies, it focuses more on commercial and industrial buildings than on residential buildings. Buildings 35,000 square feet or greater will be required to report annual energy usage through the Energy Star Portfolio Manager and demonstrate continued energy performance improvement over time (City of Boston, 2013). Only residential buildings 35,000 square feet or greater (35 units or more) will be required to participate, leaving most of Boston's housing stock unaffected by the disclosure ordinance. However, this initial passing of Boston's Building Energy Reporting and Disclosure Ordinance (BERDO) does set the stage for expanding disclosure requirements to more residential buildings in the future.

There is a growing body of research which shows that using energy information and feedback systems are effective ways to improve energy conservation and efficiency programs. Showing individual energy information in comparison to neighbor's consumption levels can influence people to use less energy. Disclosure ordinances like BERDO facilitate employing such relative information feedback systems.

In 2004, Robert Cialdini of the University of Arizona demonstrated that homeowners were more likely to engage in energy conservation behaviors if told their neighbors were implementing conservation measures than if told about potential monetary savings, environmental benefits, or social responsibility (Cialdini & Schultz, 2004). This important study established descriptive social norms as an effective way to influencing household energy consumption. This premise provided the foundation for the company Opower which sends direct mailings to over 6 million households each year showing individual household energy consumption in relation to nearby similar homes and nearby efficient homes (Opower, 2012). Simply by showing a household's energy use in comparison to its neighbors, Opower has seen on average 2% reductions in energy use amongst the households they service (Allcott, 2011). Recent research has shown the residential customer information and behavior (CIB) programs achieve on average between 2% and 7% energy savings (Mahone & Haley, 2011). This is important because it demonstrates that simply seeing energy information and relative energy performance compared to neighbors has significant and measurable impacts on energy consumption behavior.

Energy information and feedback is an effective way to motivate people to act. While utilities already have access to the energy information needed for these programs, energy information is not made readily available to the general public. There are opportunities to increase data access and optimize when, where, and how to best introduce the data. Perhaps there are moments when if presented with the suitable energy information, individuals would be more likely to act on it in a way that improves building energy performance.

One field that remains largely unexplored in the energy industry is mapping. Mapping technologies are growing more and more prevalent in other fields, and because of their close connection to real estate, they offer the opportunity to positively impact energy efficiency. Energy maps could potentially catalyze efficiency improvements in the residential market.

Mapping is a rapidly expanding arena with many practical applications. It is now common place for drivers to use voice spoken directions from their Google Maps application on their smart phones while navigating down city streets. Internet users consume more and more spatial information. Infographic maps frequently accompany popular news stories. The New York Times created popular interactive maps to illustrate the path of Hurricane Sandy (The New York Times, 2012) and to track the outcome of the 2012 U.S. elections (The New York Times, 2012).

Many maps cater to specific interests and industries. Some new mapping applications help people to search for particular businesses in an area or learn more about a particular neighborhood. Yelp.com maps local businesses and allows users to rate them and comment on them. Users are able to search for different types of business – like restaurants – and set different filters – like cuisine type, whether it is open, and distance to travel. This has real impacts on businesses – The Boston Consulting

Group reported that in San Francisco businesses with Yelp profiles generated an additional $8,000 each year (DiGrande, Knox, Manfred, & Rose, 2013). People are using maps to make decisions that have real consequences. Perhaps maps could influence decision making when it comes to energy efficiency.

Particularly relevant to energy use is that many maps deal with issues related to neighborhood livability and real estate. Walk Score (which is talked about in more detail in Chapter 3) is an online map which allows users to understand the walkability – as calculated by the Walk Score algorithm – of different neighborhoods (Walk Score, 2012). Demand for Walk Score's geospatial analysis is great and it has been incorporated into more than 10,000 websites, most of them likely dealing with real estate (Coldewey, 2011). Zillow has an interactive map which displays estimated home values and rental prices, among other details such as square footage, number of bedrooms, and number of baths (Zillow, 2013). Trulia is another popular real estate website which publishes estimated housing values on a map (Trulia, 2013). Since people are interested in the geographic location of their house or potential home, maps are a natural platform to choose to display and analyze housing-related information.

There is an interesting opportunity to combine energy performance with maps to present information to buyers and renters when they are making housing decisions. By giving decision makers the right information at the right time, on platforms (i.e., online maps) they are already using, energy maps could have the potential to dramatically impact energy efficiency. If energy consumption and building performance information were incorporated into the real estate maps people use when buying and renting homes, they could act on that information to make their housing decisions. The growing popularity of maps suggests their potential to help people understand new information and encourage them to take certain actions. Yelp users may attempt to choose the restaurant with the best reviews nearby and users of Walk Score may try to buy a home or rent an apartment in a neighborhood with a high Walk Score. An energy map could enable homebuyers to identify and purchase more efficient buildings.

Maps could play a role in encouraging people to reduce their residential building energy consumption. This category of information – building energy data – is ripe for spatial display. People are already familiar with mapping directions to and from their homes. Web maps like Walk Score and Zillow allow home-buyers and renters to search spatially for residences and quickly analyze detailed information about the building and neighborhood. Mapping building energy consumption data – obtained from the meters associated with the buildings – would enable people to consider energy costs when making housing decisions. And, displaying energy consumption data and relative energy performance on a public map may create social pressure to upgrade buildings and reduce energy use.

Given all the reasons why energy mapping could be catalyst for improving energy efficiency retrofits there is a surprising dearth of building-level energy consumption maps. Given the prevalence of home-related maps and the growing awareness of energy issues, it seems likely that there would be an audience for data rich energy consumption maps. But building energy maps lag behind other maps in quantity, relative impact, and data granularity.

Data access is the primary obstacle to making more meaningful energy maps. Electric and gas utilities are reluctant to release customer data for a number of possible reasons including privacy and safety concerns for ratepayers, fear of opening themselves up to litigation, and the future possibility to generate revenue through selling energy data. Primarily, privacy is the most stated reason for withholding data from the general public (ratepayers are able to access their individual data through bills or an online portal).

However, significant amounts of other personal data – such as property assessed value and water consumption data – are publicly available which suggests privacy concerns may be overstated. Furthermore, residential energy data could be released in such a way to mitigate concerns about safety and privacy. Finally, issues of social justice and minimizing externalities support releasing energy data. Renters and home buyers ought to be able to understand their expected energy use and costs. And, since electricity consumption has externalities, such as pollution and grid instability, communities and individuals ought to be able to understand where excess energy consumption occurs.

With better energy disclosure policies, more effective energy mapping tools could be developed. An effective energy map would be:

- publicly available so that all parties have access (e.g., ratepayers, government agencies, utilities, non-profits, and private firms)
- display information in a way that is understandable to the general public
- display information consistently across geographies and building types
- be developed using an API that could be displayed on third party sites and maps
- and be built upon a database which uses a standard data and building taxonomy

Chapter 2 – Research Questions and Methodology

This thesis explores how an energy map could catalyze energy efficiency upgrades, specifically in the residential market. I will analyze what data is necessary to build an energy mapping platform that remotely assesses energy efficiency potential. I will examine what policies are necessary to access residential energy data. The three main questions I seek to answer are what data is necessary to map building level energy performance, what policies are necessary to access that data, and how should energy information be displayed in a map for the most meaningful impact.

Interviews were conducted with relevant stakeholders who had expertise in energy data access, energy mapping, data management, energy data analysis, residential buildings, multifamily buildings, commercial buildings, and marketing and outreach of energy efficiency. A summary of the interviews is found in Appendix A and findings are incorporated into relevant topic areas throughout the paper. The interviews conducted were:

1. Michael Blasnik, Principal at Michael Blasnik & Associates
   Michael Blasnik & Associates conducts statistical analyses of large energy data sets for utilities and other organizations and specializes in projects related to energy efficiency.

2. Ed Connelly, President of New Ecology
   New Ecology is a non-profit organization that promotes sustainable development through research, project management, and technical assistance, among other things. New Ecology developed WegoWise which is an online platform for collecting and managing energy data from multi-family residences.

3. Ryan Davis, Director of Programming at EnergyIT
   EnergyIT developed Gainesville Green and Tools for Tenants which are two online maps which display energy information for individual buildings in Gainesville, Florida.

4. Joseph Ferreira, Professor of Urban Information Systems, MIT
   Professor Ferreira teaches in the Department of Urban Studies and Planning at MIT and has previously conducted research on modeling energy consumption using utility energy

data and tax assessor records.

5. Bennet Fisher, CEO of Retroficiency
   Retroficiency provides tools to analyze commercial buildings energy performance using interval energy data as the primary input. Their clients include energy service providers, utilities, and building owners.

6. Eric Graham, Director of Energy Efficiency Financing at Next Step Living
   Next Step Living is a residential energy efficiency company which conducts energy assessments and retrofits in New England.

7. Meghan Shaw, Community Outreach Director, Cambridge Energy Alliance
   Cambridge Energy Alliance is a city program which promotes efficiency to residents and businesses in Cambridge, Massachusetts.

In Chapter 3, to explore how energy maps and increased data access could transform the residential energy efficiency market, I examine existing precedents in energy maps and energy assessments. I evaluate five existing online energy maps as precedents in energy mapping. The five were selected because they are online, interactive, and relatively new, which is important in the rapidly changing fields of mapping, energy disclosure, and digital technologies. I examine what data was used to build the maps, what the potential impacts of the maps were, whether they were successful, and what lessons could be learned from them. Three other non-energy maps were also examined for their relevance to real estate mapping and housing decisions. The maps explored were:

1. New York City Building Energy Consumption Map
2. Los Angeles Electricity Consumption Map
3. EnergyView: Cambridge Energy Map
4. Gainesville Green and Tools for Tenants
5. Cambridge Solar Map
6. Non-energy maps: Walkscore, Padmapper, and Craigslist

In Chapter 4, I evaluate four possible energy assessment tools. If an energy map displays a building performance score, a tool or platform will need to be used to analyze and rate residential buildings. Different tools require different data inputs, some of which may be publicly available and others which might not be and therefore could not be used in a public map. I examine what the necessary data inputs are and how successful the tools could be for a remote and relative energy assessment for an energy map. The energy assessment tools evaluated were:

1. Opower
2. Home Energy Yardstick
3. Home Energy Rating System (HERS – California)
4. Home Energy Saver and SEED

In Chapter 5, I examine data transparency and disclosure. This includes an examination of the Green Button Initiative which was a utility-led initiative to increase customer access to energy data and to standardize the taxonomy of energy data. I also discuss current disclosure initiatives that U.S. cities have implemented and not the obstacles to implementing disclosure policies and enforcing compliance.

In Chapter 6, I recommend actions for federal, state, and utility actors to increase data access and to standardize data management systems. I also outline the necessary components for a successful energy map which impacts energy efficiency in the residential sector.

Finally, Chapter 7 concludes with a discussion on the growing importance of energy efficiency, mapping technologies, and advances in data collection and energy technology.

Chapter 3 – Related Work in Energy Mapping

This chapter surveys five recently developed energy maps: the New York City Building Energy Consumption Map, the Los Angeles, Electricity Consumption Map, EnergyView, Gainesville Green, and the Cambridge Solar Map. These energy maps were selected because they are relatively new, they are online (with the exception of EnergyView), and they are interactive. Relevant non-energy map examples like Walk Score and Craigslist are briefly explored because of their relationship to the real estate market. From these maps, lessons can be learned about data access, data display, and the potential impact of energy maps.

Energy mapping is a relatively new field – many mapping applications are confined to academia or used for internal analysis in the private sector. However, to achieve maximum impact, energy efficiency mapping tools need to be available to the general public and they need to display information for individual buildings. A survey of the energy mapping field conducted by a MIT graduate student in 2012 examined eight energy maps. Of those eight, only two displayed building-level data and of those, only one was a publicly available for use online (Reul & Michaels, 2012). The majority of the maps analyzed aggregated data to the block or county level. While this may be helpful for policy makers, it does not provide helpful information to homeowners and tenants who are incurring the costs of energy consumption. An effective energy map would display data at the building level and provide comparison between similar building types so owners would know if they are performing in relation to their neighbors. This chapter evaluates how five energy maps are addressing concerns of data access, individual privacy, and visual display.

New York City Building Energy Consumption Map

Researchers at Columbia University created an interactive map in early 2012 which shows building energy consumption at the block level in New York City (see Figure 2). Their study built a model to estimate energy end-use intensities in buildings for space heating, water heating, electricity for cooling, and electricity for other applications. The Columbia Team was able to access robust energy and building data, which is unusual in many other cities. The City provided annual energy data by zip code after gathering the data from the major utilities. Additionally, the researchers were able to use the geo-rectified database called PLUTO which updates building stock information annually (Howard, Parshall, Thompson, Hammer, Dickinson, & Modi, 2012).

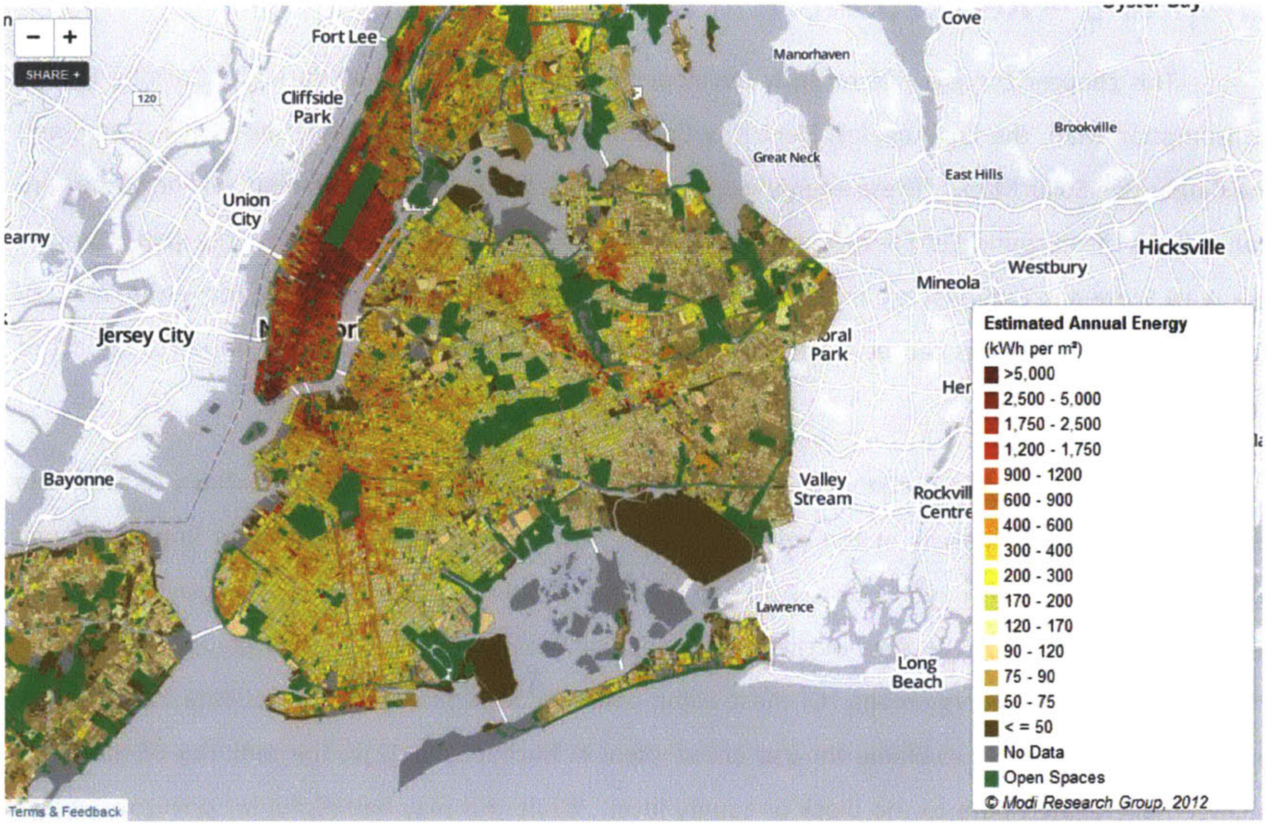


Figure 2 - Screen capture of the energy map created by engineers at Columbia University (Columbia Engineering, 2012).

The researchers used a map to visualize their information arguably because a spatial understanding of energy end-use was a critical component of their study. Their stated intention was that their energy map could be used to evaluate the potential for distributed generation and the mapping of information illustrated the local uses of energy. As they noted, "Spatially distributed energy use information can permit one to identify cost-effective engineering retrofit opportunities. A solar resource on one building's rooftop could be valuable for another building nearby. A utility may need to identify areas where local generation may offset costs of increased transmission to accommodate additional capacity from plug-in hybrid vehicles," (Howard, Parshall, Thompson, Hammer, Dickinson, & Modi, 2012). The research and subsequent map are thus designed for an audience of policy makers, researchers, and people interested in designing distributed generation systems. Although publicly available, the map does not present helpful information to the lay person who may be interested in understanding the energy performance of the building they occupy or own.

An interesting development with the interactive map (published at modi.mech.columbia.edu/nycenergy/) is that it had a commenting feature enabled. Many commenters noted that the energy use was normalized by lot size as opposed to building floor area. As one commenter wrote [sic], "kw/h per square meter of land isn't very useful in that it obviously penalizes tall buildings. kwh used per square meter of building floor area would be a better metric. as is this map is basically just a height map of the city," (Barrett, 2012). The comments show that while this map may not have been the most useful to the general public, there is a broader audience interested in energy maps that is willing to participate in discussions based on spatial energy information.

The lead researcher Bianca Howard noted, "The lack of information about building energy use is staggering...We want to start the conversation for the average New Yorker about energy efficiency and conservation by placing their energy consumption in the context of other New Yorkers. Just knowing about your own consumption can change your entire perspective," (Columbia Engineering, 2012). One of the stated intentions behind this map was for New York residents to understand the energy consumption of the buildings they live in; however, the complexity of the analysis conducted is geared more towards a research or policy-oriented audience, the map does not show building-level data, and commenters noted how it was not useful to individual occupants. The general public would not be able to understand much of the information presented nor have an idea of what actions should be taken given the information in the map. Indeed, the authors note that the map is a "...valuable tool for determining cost-effectiveness and policies for implementing energy efficiency and renewable energy programs," (Howard, Parshall, Thompson, Hammer, Dickinson, & Modi, 2012), emphasizing it was designed for policymakers, not the general public.

While the New York City Building Energy Consumption map made a graphically compelling visualization of energy data, it was not necessarily informative or empowering for people seeking to improve the energy efficiency of their buildings. The aggregated data masked identify individual buildings which may be ripe for efficiency upgrades. A map which provides a more granular view of energy use at the building scale would enable people to take more specific actions in the buildings they own and occupy.

Los Angeles Electricity Consumption Map

In March 2013, researchers at UCLA published an interactive map of block-level energy use in Los Angeles. Using data from the Los Angeles Department of Water and Power (the municipal utility) and the American Community Survey, the map displays energy use and characteristics at the block group level (see Figure 3). The map shows average monthly electricity consumption between January 2011 and June 2012. For each block, users are able to see more detailed information including land use composition, average income, average year built, and block group square meters (California Center for Sustainable Communities, 2013). Researchers were able to access the energy data from the local utility because it was municipally owned. Moving forward, the research team hopes to expand the map into territories covered by private utilities and access data through non-disclosure agreements (La Monica, 2013).

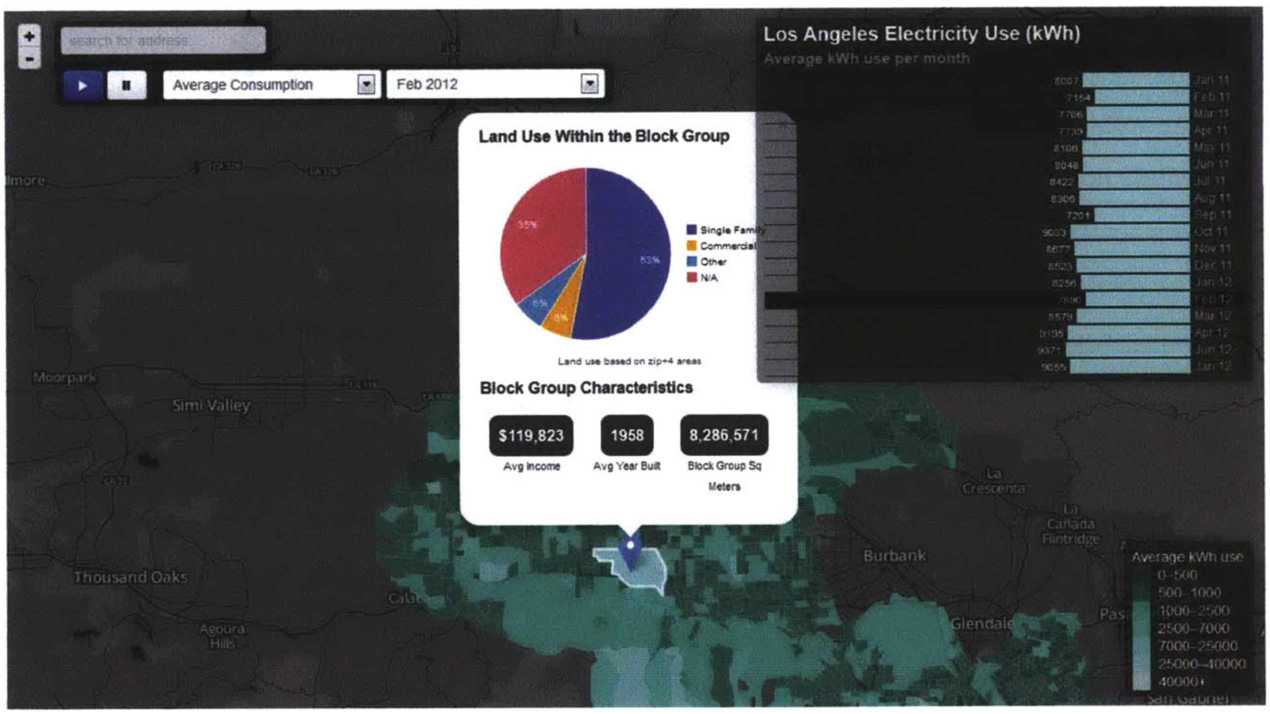


Figure 3 - Map of Los Angeles electricity use at a block level created at UCLA (Murdock, 2013).

This map offers a more detailed perspective than the Columbia energy map by including land use, income, and building age information. Additionally, the map shows changes over an 18-month period, so users can see seasonal variation in energy consumption. During summer months, electricity consumption increases across the city. Also interesting to note is which block groups exhibit seasonal

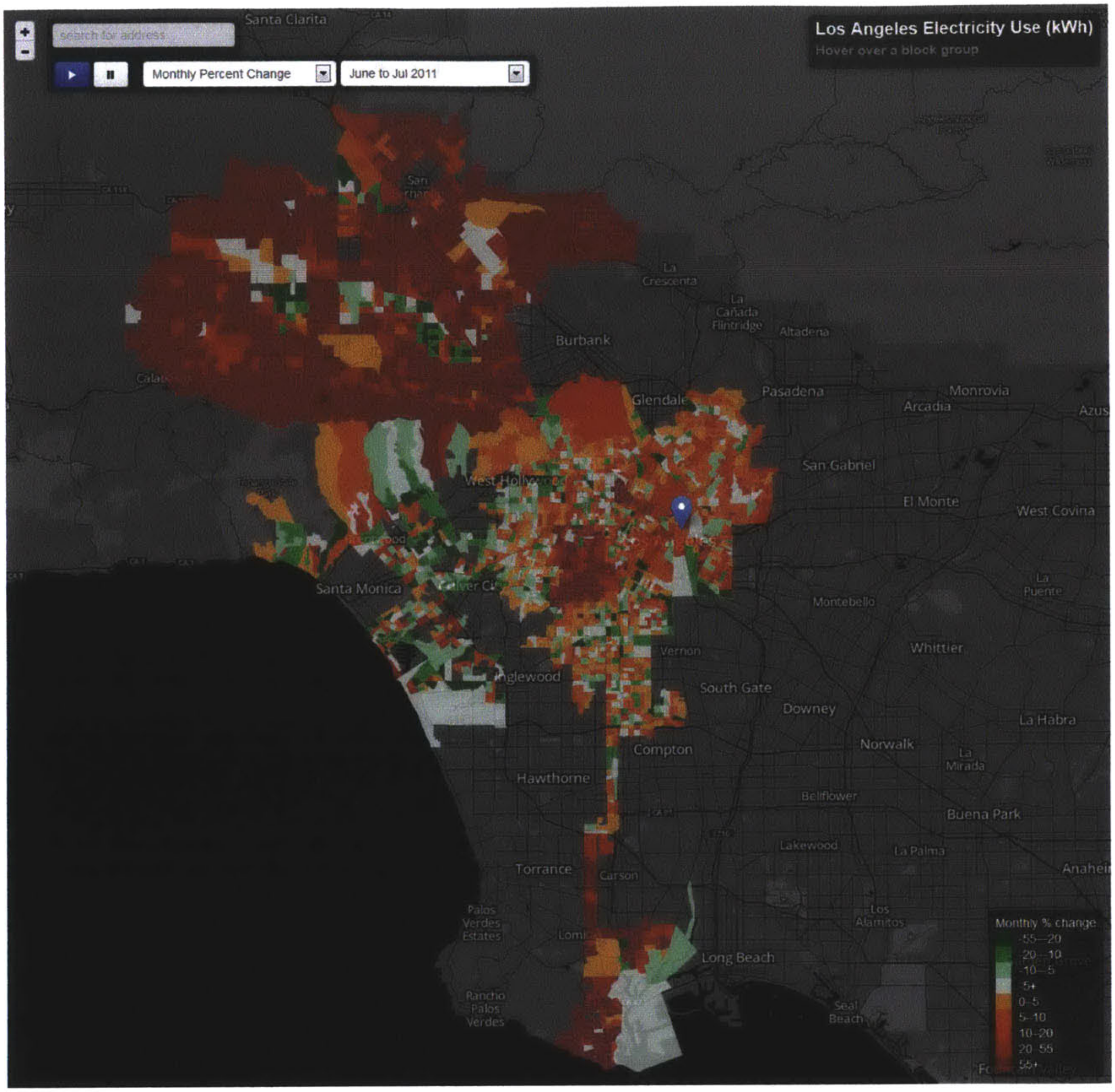


Figure 4 - LA map showing monthly percent change in kWh consumption from June to July 2011 (Murdock, 2013).

variation and which do not. From June to July 2011, there is a dramatic monthly percent increase in electricity consumed, presumably from air conditioning, in the northern parts of LA (see Figure 4). Perhaps outreach could be focused in these areas to change behavior patterns around air conditioning. Conversely, perhaps areas that consistently display high levels of consumption would be ripe for deep retrofits. The L.A. map certainly offers new lenses to examining energy consumption at the city scale.

However, by aggregating data to the block level, the information does not speak to individual building owners or tenants. An owner could not use the map to understand how their building is performing nor how to take action to improve their building. MIT Technology review noted, "For consumers, the interactive map shows how each block compares to others and consumption patterns by season. But the Web app is more directly aimed at the municipal utility, the Los Angeles Department of Water and Power (LADWP), and city planners," (La Monica, 2013). It seems privacy concerns influenced the decision to display block level data.

EnergyView: Cambridge Energy Map

In 2011, researchers at MIT conducted another academic study which included mapping energy consumption. This map moved beyond aggregated data and showed individual building performance; however, because of a non-disclosure agreement related to the utility-provided energy data, this map was not publicly published. Conducting the analysis in Cambridge, Massachusetts, the researchers used monthly electric and gas bills for 6,500 buildings from the local utility. They also collected building characteristic information online tax assessor records and other geographical information from GIS records. Using these data sets, they built a model to predict energy consumption. The resulting EnergyView map (see Figure 5) compared actual performance to predicted performance, enabling users to view outliers (i.e., buildings which perform much better or worse than similar buildings were color coded with varying intensities of green or red, respectively) (Kolter & Ferreira, 2011).

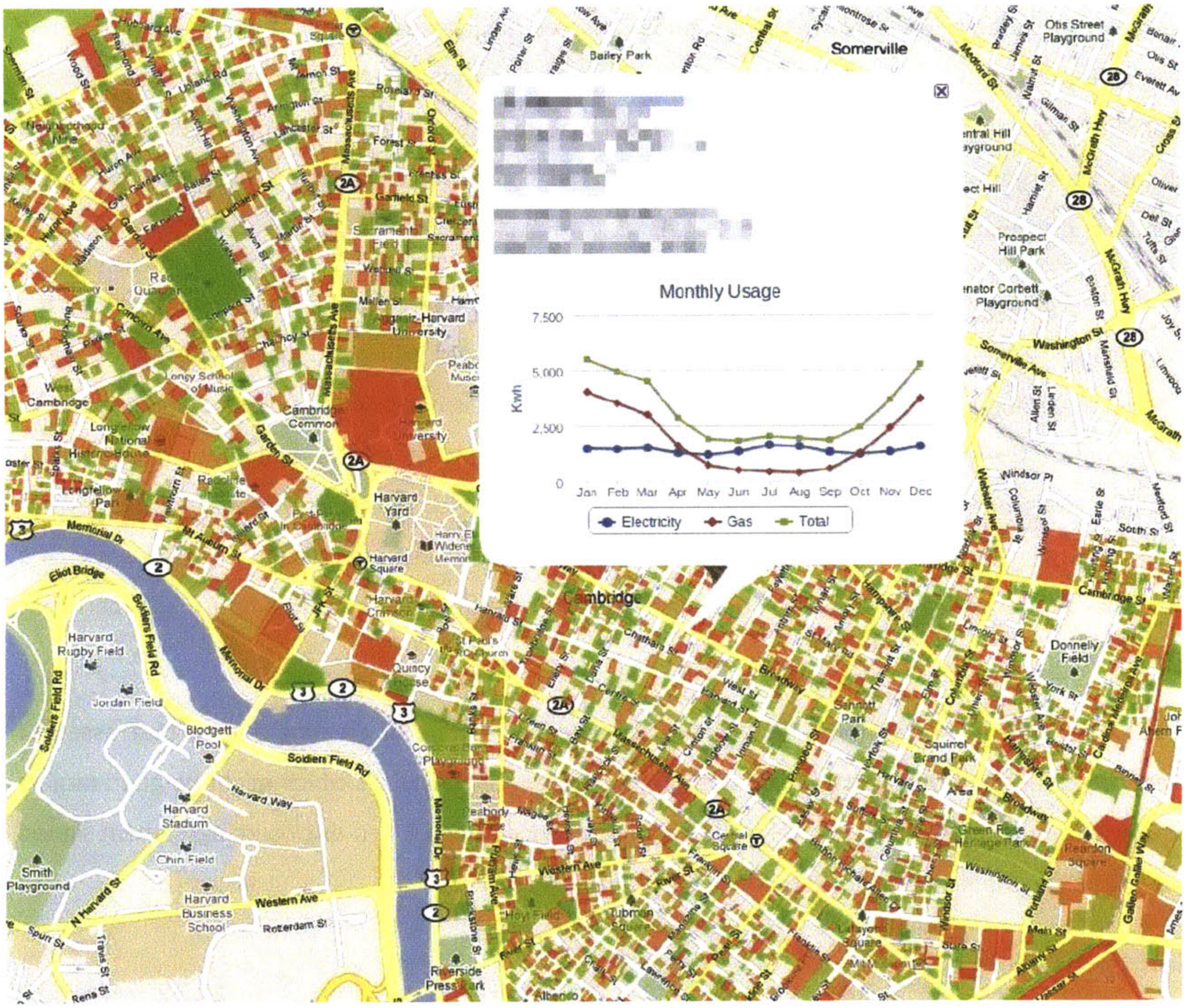


Figure 5 - Mock-up of the EnergyView map developed by researchers at MIT (Kolter & Ferreira, 2011).

The researchers experienced difficulty in matching utility data with tax assessor and GIS records. The utility – in this instance NSTAR – tracks accounts by meter number. There is no indication whether a meter is for an apartment, common spaces, or perhaps a detached garage. Sometimes a single home will have multiple meters attached. The utility addresses do not necessarily match city addresses and so it can be difficult to correlate a meter with the tax assessor records which relays the building characteristics. Matching utility data to the tax assessor records is also difficult because tax assessor records are catalogued by taxable entity while utility records are kept by meter number, resulting in two distinct databases which do not necessarily have linking identifiers (Ferreira, 2013).

With their model, the researchers were able to explain 75% of the variance in energy usage by the building characteristics collected from public records (i.e., tax assessor and GIS). The remaining variance is presumably due – at least in part – to occupant behavior. EnergyView visualizes actual usage to predicted building usage. The authors postulated that utilities or community-organizations could use the map to target outreach efforts and resources to neighborhoods or buildings which displayed poor expected performance (Kolter & Ferreira, 2011).

EnergyView underscores the benefit of granular, building-level data. Other maps, such as the Columbia and Los Angeles maps, aggregate data at a block level. While this may be useful for policy makers, a building-level understanding of energy performance is necessary for owners and tenants to take action. Aggregated data does not speak to the problems of specific buildings and moreover proximity does not necessarily correlate with performance which means aggregated data does not necessarily help target specific homes which would benefit the most from efficiency upgrades (i.e., if a house has a poor energy score, that does not necessarily mean their neighbor's house also performs poorly).

EnergyView was an important test in an academic setting of creating a map that assessed energy efficiency potential and enabled users to identify specific buildings which might be good targets for efficiency upgrades. Unfortunately, due to privacy concerns and a non-disclosure agreement signed with the utility, the map was never made publicly available.

Gainesville Green and Tools For Tenants

EnergyIT is the only company currently which has developed public maps displaying energy data for individual homes. In the early 2000s, Energy IT was working for an individual interested in carbon credit banking. However, as the advancement of carbon credits stalled, EnergyIT looked more toward energy efficiency and data transparency. The carbon issue was dropped, but EnergyIT was left with a rich data set from that experience. The city of Gainesville donated money to build a map and since the municipality owns the local utility, city officials agreed to continue to share energy data with EnergyIT for mapping purposes (Davis, 2013).

Around 2006, EnergyIT launched the first iteration of Gainesville Green, an interactive map (see Figure 6) which allows users to view gross electricity, natural gas, and water consumption (Davis, 2013). The map displays the nearest 100 homes and color codes the dropped pins from dark red to dark green to illustrate high bills to low bills, respectively. Users have the option of normalizing the data per 1000 square feet, choosing a comparison between the nearest 100 homes or similar homes, and viewing historic yearly data starting in 1999. Users can also add individual homes to a group and then compare only homes within that group (EnergyIT, 2011).

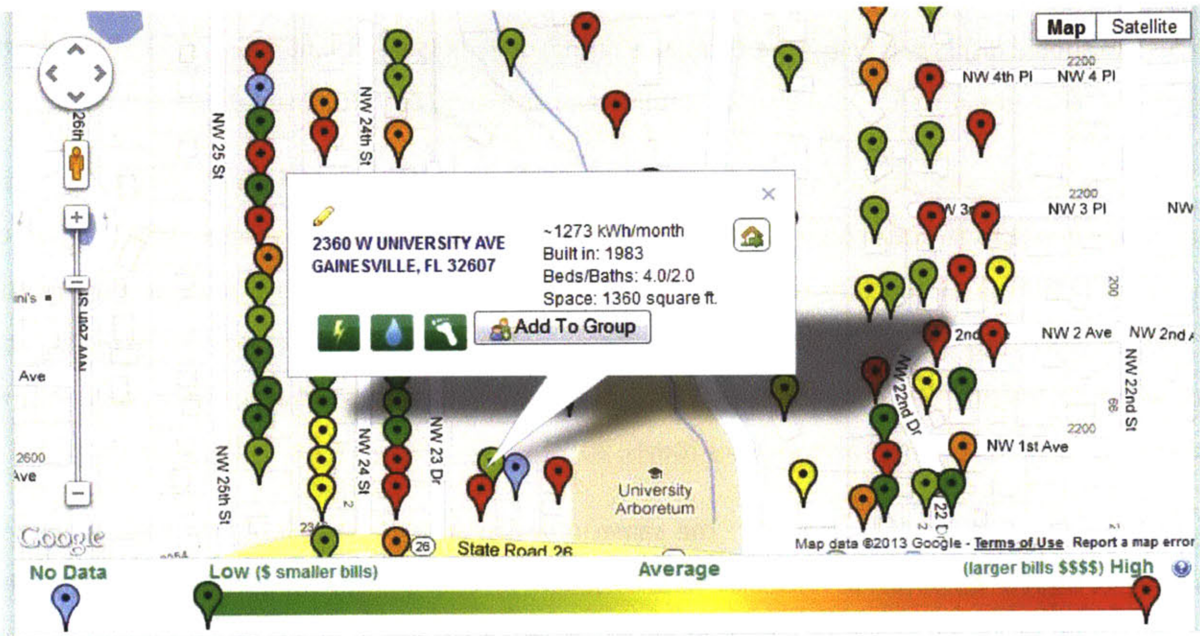


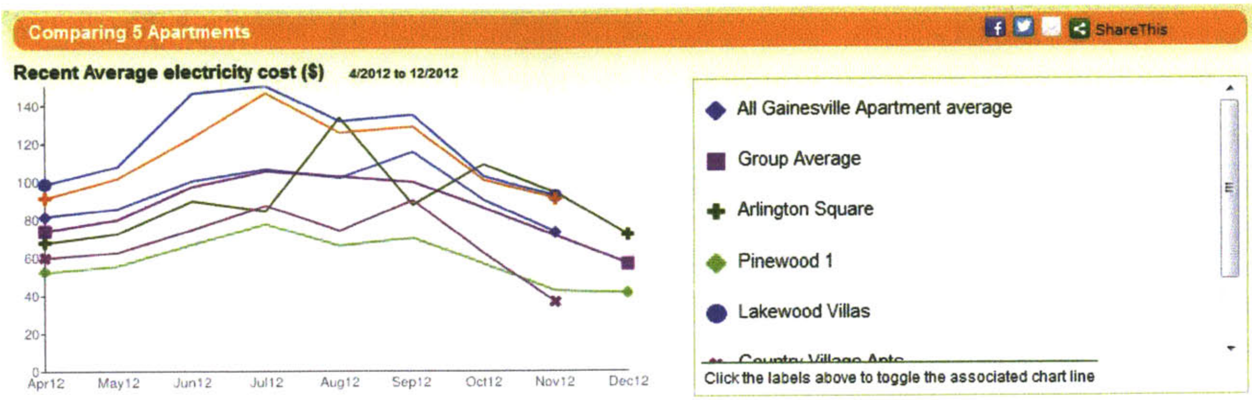
Figure 6 - Gainesville-green.com allows users to compare the energy use of specific homes in Gainesville, Florida (EnergyIT, 2011).

Notably, Gainesville Green shows total monthly electricity and gas consumption and allows the user to normalize that data by 1,000 square feet (EnergyIT, 2011). EnergyIT does not include an energy rating or score on the map. Ryan Davis, Director of Programing at EnergyIT, explained that the early iterations of Gainesville Green displayed more sophisticated energy analysis that pulled incorporated data from tax assessor records. However, after receiving SBIR funding to conduct user testing on the web map, EnergyIT discovered that most people – those without detailed energy knowledge – did not respond to the sophisticated energy performance ratings. Focus group evaluations of Gainesville Green suggested users from the general public were most concerned with energy costs – they cared more about dollar amounts than kilowatt-hours or carbon savings. Subsequently, EnergyIT went through a process of simplifying their online map to meet the interests of users. They proceeded to filter out the complex features and leave gross energy consumption and dollars as the default display on the map (Davis, 2013).

However, Davis also noted that other more specialized audiences responded to the analysis. EnergyIT realized the more complex analyses layered on top of their information benefitted policymakers, planners, and engineers but was too complex for a general audience. Policymakers are interested in more sophisticated performance ratings as are energy efficiency contractors who can use the information to target potential clients (Davis, 2013). This lends credence to the argument that an energy map should display an energy performance rating, or in an ideal situation, users could choose to toggle between displaying gross energy consumption and an energy performance rating.

EnergyIT was awarded a Department of Energy grant to build a second similar map – Tools for Tenants (www.toolsfortenants.com) – which addresses rental properties in Gainesville. This was part of an initiative with the local utility to try to reduce energy consumption in the hard-to-reach rental market. Tools for Tenants was an attempt to give renters information on energy costs which might then influence their housing decisions. EnergyIT hypothesized this could eventually incent landlords to improve their building's energy performance (Davis, 2013).

Tools for Tenants displays largely the same information as Gainesville Green with some key differences. There is no option to normalize data by square feet in Tools for Tenants. EnergyIT used the tax appraiser database to find square footage for the homes displayed in Gainesville Green. However, the appraiser database does not have square feet for the rental market. EnergyIT attempted to manually build the data set but discovered that it was time-consuming and the data grew stale very quickly. Similar to Gainesville Green, Tools for Tenants allows users to select apartment buildings for a group comparison (see Figure 7).



View a map of these apartments

How are these calculated?

Apartment	Floorplans gathered from apartment websites	Units	Electricity average monthly kWh	Cost average monthly estimate based on published electricity rates	Gas average monthly therms	Carbon average monthly tons of CO_2e
Arlington Square 113 NW 3RD AVE, Gainesville FL 32601 more	• Beds: 0-3 • Baths: 1-3 • Size: 312-1444 square feet • Rent: 599-1819	405	645	$89	-	0.30
Pinewood 1 4151 NW 43RD ST, Gainesville FL 32606 more	• Beds: 1 • Baths: 1 • Size: 600 square feet • Rent: 460	174	427	$58	-	0.20
Lakewood Villas 700 SW 62ND BLVD, Gainesville FL 32607 more	• Beds: 1-3 • Baths: 1.5-3 • Size: 704-1450 square feet • Rent: 700-1132	210	839	$120	-	0.39
Country Village Apts 2700 SW ARCHER RD, Gainesville FL 32608 more	• Beds: 1-3 • Baths: 1-2 • Size: 745-1000 square feet • Rent: 595-1020	90	495	$68	-	0.46
Asbury Park Apts 5333 SW 75TH ST, Gainesville FL 32608 more	• Beds: 1-3 • Baths: 1-2.5 • Size: 800-1524 square feet • Rent: 875-1300	206	798	$112	-	0.37

Figure 7 - Tools for Tenants allows users to build custom groups of apartment complexes and then compare their energy use and cost (EnergyIT, 2011).

Reaction to Gainesville Green and Tools For Tenants has largely been positive. Individuals in Gainesville have the option to opt out of having their home's energy by displayed on the map, but only a small percentage has chosen to do so. At one point, an energy efficiency firm used Gainesville Green to identify homes for outreach. A property owner of large apartment buildings also contacted EnergyIT inquiring how it could reduce the energy consumption of its buildings after he had seen his buildings on the Tools For Tenants map. And people regularly comment that they like the graphic display of the map (Davis, 2013).

Ryan Davis, the Director of Programing for Energy IT, notes that the maps could be more powerful with a coordinated marketing effort. There was not a large publicity push and so not as many people know about the maps as possibly could. He also noted that different audiences like to see different types of data and analysis. Homeowners and renters are interested in dollars and cents. And if they do comparisons to other buildings, they want to see how they perform compared to their friend's homes or their neighbors – people they know. He suggested that creating a game or competition around energy consumption reduction using the map could be a good motivator to spur investment in efficiency upgrades. Contractors are interested in the normalized data or comparing project developments to each other. And policy makers are interested in more aggregated and analyzed data that can help them make policy decisions (Davis, 2013).

An important takeaway from Gainesville Green is knowing what audience the map is targeting and making sure the data is curated to speak to them. Homeowners and tenants are most interested in energy costs, while policymakers, researchers, and contractors desire a greater level of analysis. It is also good to include an opt-out policy which allows people to withdraw their building from the map. While a some people may choose to remove their information from the map, the Gainesville Green experience suggests most people will not opt-out. Also, an energy map should be publicized in a marketing campaign and in public outreach efforts to ensure the widest possible audience.

Cambridge Solar Map

While building-level energy consumption maps are rare, citywide photovoltaic (PV) potential maps are much more common. The Cambridge Solar Map (see Figure 8) was developed by researchers at MIT's Sustainable Design Lab and the design firm Modern Development Studio for the city of Cambridge, Massachusetts. Built on the Google Maps API, the Solar Map enables users to scan the city or search specific addresses and see a detailed color-rating of solar potential across all building roofs. The map also includes information on estimated annual kilowatt-hour production, potential savings, photovoltaic system cost including incentives and rebates, and carbon emissions reductions (Modern Development Studio, LLC, 2012).

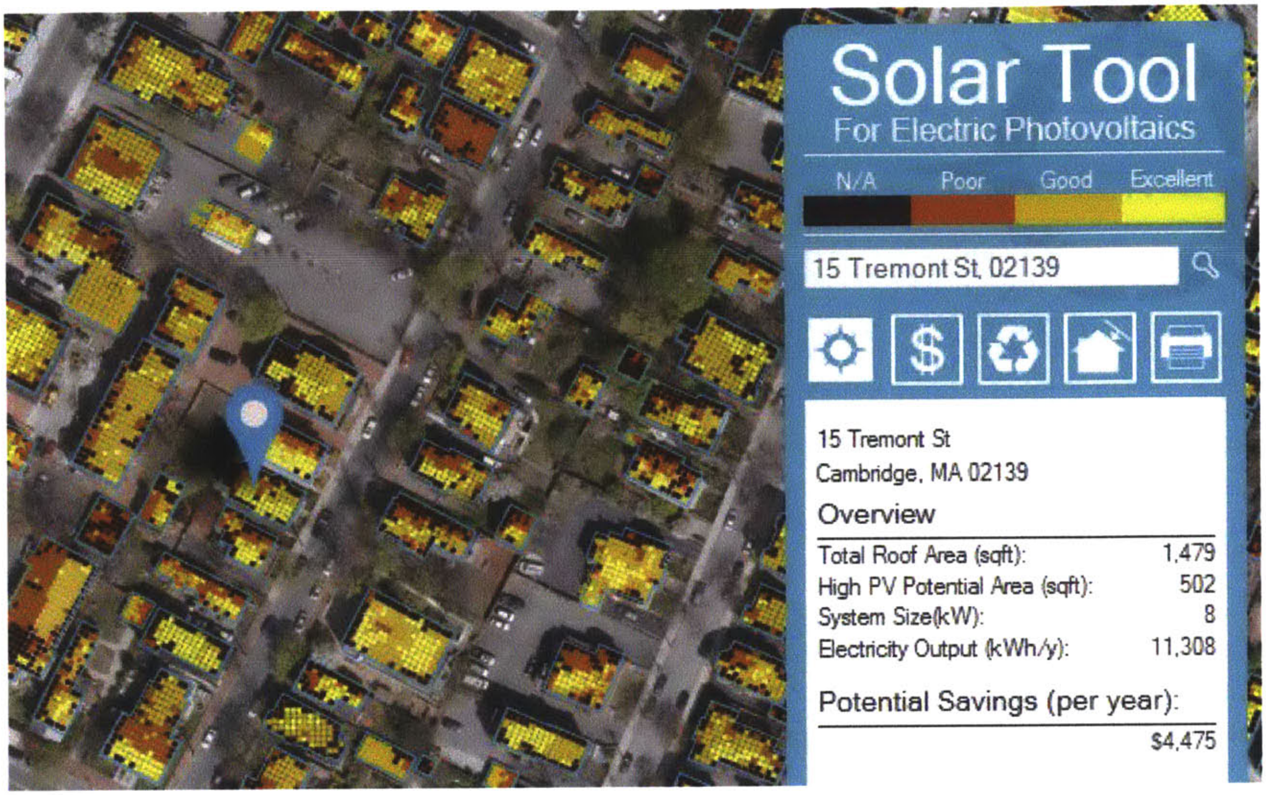


Figure 8 - Screen capture of the Cambridge Solar Map displaying roof area, solar energy potential in kWh, and potential savings for a sample building (Modern Development Studio, LLC, 2012).

MIT's Sustainable Design Lab was able to create a highly-detailed model to estimate roof-specific photovoltaic production capacity by using LiDAR data. In 2010, Cambridge paid for a LiDAR survey conducted by aircraft. LiDAR is a laser technology which collects highly accurate information on vertical heights and their geolocations. Along with a climate-adjusted solar radiance simulation, this 3D data enabled the researchers to conduct refined analysis of PV potential of all roofs in Cambridge (Jakubiec & Reinhart, 2012).

The Solar Map has several relevant points which relate to an energy consumption map or energy efficiency map. It targets specific buildings, it provides energy estimates, and cost/savings estimates. The researchers also noted on the importance spatializing information to individual buildings, "...homeowners and businesses can engage with the map through the ability to identify their roof specifically and notice how its unique form produces varied suitability for photovoltaic installation. Essentially, users of the map feel like the simulation results are personalized to their building which is important to produce confidence in the results and to increase interest in the goals of the map," (Jakubiec & Reinhart, 2012, p. 9). This suggests that the personal interaction people might have with a similar building-specific energy consumption map could also increase their likelihood to act on the information.

Other Relevant Map Examples

Some tools already exist which suggest there is potential for a map geared at displaying home or rental unit energy performance to be successful. Mapping technologies are increasingly present in our lives: Google Maps is nearly ubiquitous across the United States, Yelp – a popular online restaurant review system – maps nearby eateries for users to choose from, and people regularly check-in on Foursquare to indicate to friends where they have been. Maps are also increasingly being used to make housing decisions, which underscores the ability for an energy map to influence the housing choices renters and buyers make.

Walk Score (www.walkscore.com) is an online map which rates the walkability of different neighborhoods based on metrics like number of nearby restaurants, schools, and the availability of other amenities (see Figure 9). Users can evaluate how walkable a neighborhood is before they decide to live there. Over 10,000 websites that list rental apartments use Walk Score and a year ago the company developed a new apartment search tool (Coldewey, 2011).

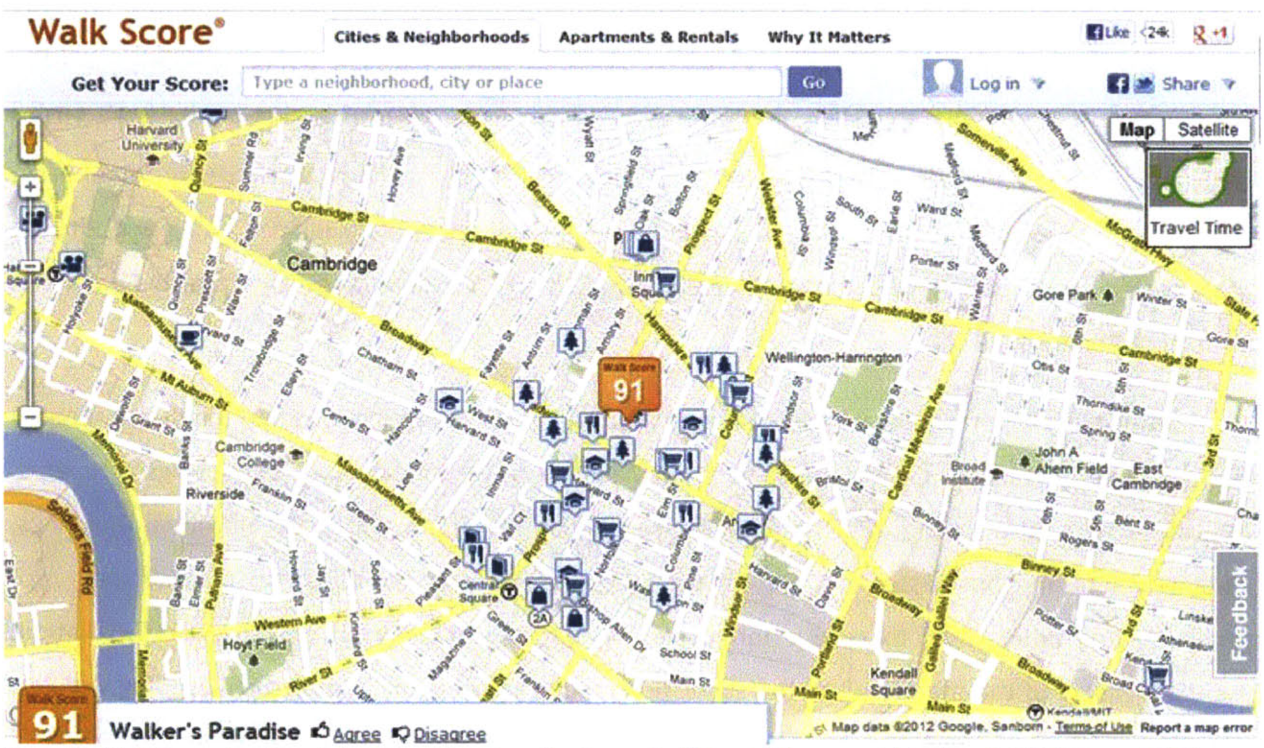


Figure 9 - Walk Score developed algorithms to determine the walkability of different neighborhoods (Walk Score, 2012).

One of the over 10,000 websites which uses the Walk Score plug-in is PadMapper (www.padmapper.com). PadMapper pulls apartment listings from Craigslist.org – a popular site where people post apartment listings among other things – and displays them geographically using Google Maps. One of their included information tabs is Walk Score (see Figure 10). It could be feasible for sites like PadMapper to also include energy information from a possible energy map, thus dispersing energy awareness even further and encouraging people to consider energy costs when making housing decisions. Moreover, the technology for integrating data sets and creating mashups is improving, so plugging-in energy data will be easier to do.

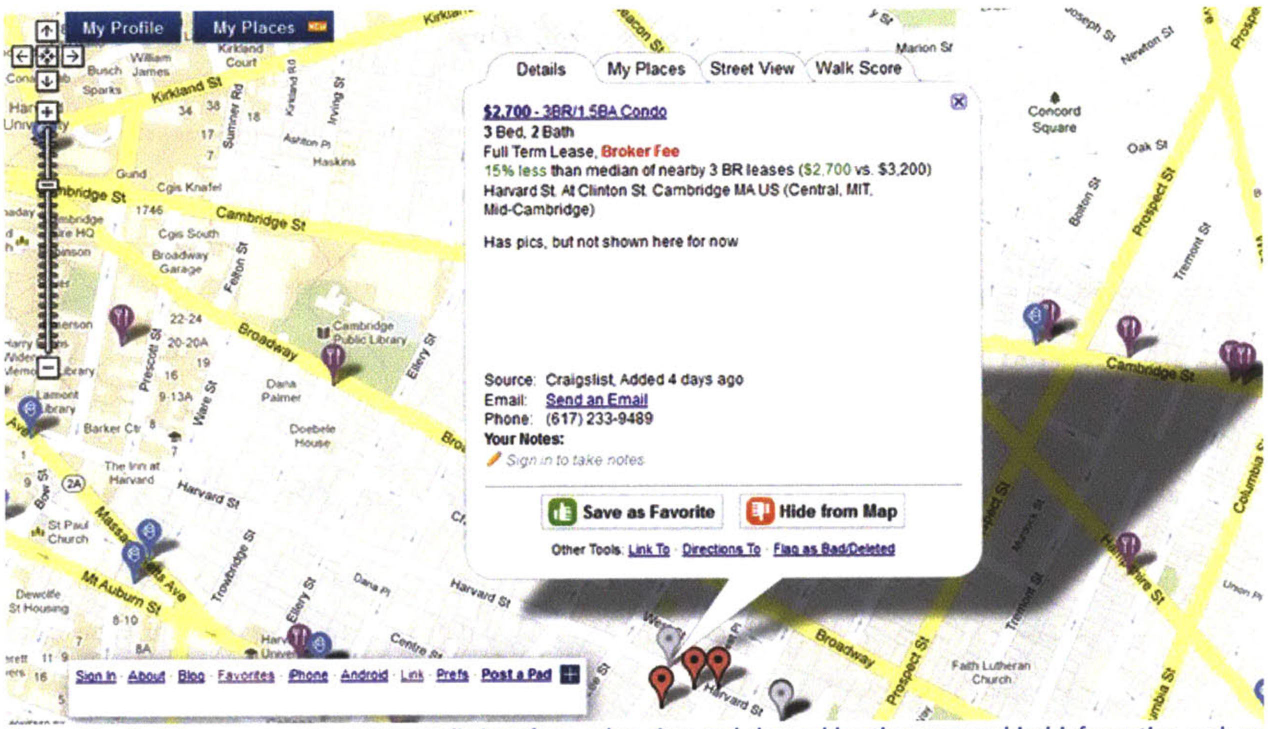


Figure 10 - PadMapper sources apartment listings from other sites and then adds other geographical information such as nearby restaurants, bars, schools, and more. It also incorporates Walk Score information with each apartment listing profile (PadMapper).

Craigslist itself recently launched an apartment mapping tool where users searching for apartments can display results on a map (see Figure 11). Since rental seekers already frequently turn to Craigslist to find an apartment, this map could become a popular tool. Perhaps the Craiglist map could incorporate Energy Map information which would help apartment seekers make leasing decisions. If a popular site likes Craigslist.com included the Energy Map information, this could have potential to influence landlords to improve their buildings.

Figure 11 - Craigslist.org now includes a map for viewing apartment listings. Including energy information on this map could prove helpful to apartment seekers and could help convince landlords to invest in upgrades (Craiglist.org, 2012).

Lessons Learned on Energy Maps

From the evaluation of existing energy maps, there are some key takeaways about strategies to make an energy map as impactful and compelling as possible:

- Present building level data instead of aggregated data to encourage efficiency changes by individual property owners.
- Include information which is relevant to different user groups, such as renters, homebuyers, property owners, and policymakers. Present information in a way that is understandable to the desired target audience.
- Allow individual property owners to opt-out of having their building's information included on an energy map.
- Publicize the map in marketing and outreach campaigns to reach a large audience and maximize the map's potential impact.

Chapter 4 – Remote and Relative Energy Assessments

As noted in the introduction, there is a growing body of research which suggests that descriptive social norms are quite effective at influencing people's energy behaviors. A study conducted in 2004 by researchers at Arizona State University and California State University demonstrated that telling people their neighbors implemented energy conservation measures made them more likely to reduce their own energy consumption than telling them about potential monetary savings, environmental benefits, or social responsibility (Cialdini & Schultz, 2004). A 2011 report by Energy and Environmental Economics noted that information and feedback energy efficiency programs regularly see between 2% and 7% reductions in energy consumption (Mahone & Haley, 2011). Incorporating a comparison of energy performance on an energy map could be an effective way to leverage descriptive social norms and encourage people to adopt energy efficiency strategies.

Creating a map which displays comparisons of energy performance of different buildings requires analyzing and scoring multitudes of buildings without going inside them. In this paper, analyzing building energy performance without collecting data at the site of the building is referred to as a remote energy assessment. Since these touchless assessments use less detailed data than onsite energy audits, their ratings will necessarily be less precise and potentially less accurate than an in-home audti. Even without the detail of an onsite audit though, a citywide remote assessment of residential building stock could still offer meaningful ratings which encourage energy efficiency by showing the relative energy performance of buildings. In this paper, a relative energy assessment means showing how one building performs relative to another building with similar characteristics.

To maximize the impact of an energy map and maximize its ability to influence users through descriptive social norms, it should visually display a relative energy performance rating for all residential buildings within a particular municipality or reason. This performance rating would need to be conducted remotely and its output should be a relative energy assessment so that users can compare different building types. The relative energy assessment score would need to be easily understood and trusted by the general public.

This chapter examines four existing relative energy assessment platforms and evaluates how appropriate they would be for an energy map. Relative energy assessments compare the energy performance of similar buildings. Remote energy assessments are those that can be conducted without an in-home audit. For the purposes of an energy map, a remote energy assessment would need to be used and ideally it would produce a relative energy performance rating. This chapter explores whether it would be possible to conduct a relative energy assessment remotely, what data sources are needed for a remote and relative energy assessment, and which existing assessment platforms would be suitable for an energy map.

Remote Energy Assessments

In order to accurately map energy assessments or energy efficiency potential, it would be necessary to conduct an energy assessment and assign an energy performance rating. It would not be feasible to conduct an in-building audit of every home in a city, so in order to portray and energy performance score on a map, remote assessment would be necessary.

Some companies have already developed tools to conduct remote energy assessments. Retroficiency is a Boston-based energy-assessment firm which has developed tools to perform touchless audits on commercial buildings. Using 15-minute interval energy data, Retroficiency compares the building's energy information to their library of energy models. Their algorithms can detect defining characteristics regarding the building and its use, including determining separate heating, cooling and lighting loads; what kind of equipment it houses; and the daily patterns of use, among other things. Based on this information, Retroficiency makes recommendations regarding equipment upgrades, building controls, and potential energy savings (Fisher, 2012). Using only energy consumption data, Retroficiency can provide accurate and detailed energy assessments in a short amount of time with minimal inputs from building owners. Using this information, Retroficiency's clients – which include utilities, energy auditors, and property managers – are able to implement or suggest energy efficiency improvements which improve building performance.

Retroficiency's energy assessment tools demonstrate the power of energy data to transform the efficiency market through faster, less expensive, and more convenient assessment tools. Access to energy data presents the opportunity for many other innovative developments as well. However, while some commercial buildings with smart meters are able to leverage tools like Retroficiency's, easy access to energy consumption data is a rare commodity. In the residential sector, this is especially true.

While challenging, there are some companies collecting and analyzing residential energy data. WegoWise offers energy management software for multifamily buildings. After collecting individual utility account information from tenants, property managers and building owners are able to monitor and analyze monthly gas, electricity, and water use. They can compare different buildings within their portfolios and compare their buildings to similar buildings in WegoWise's database. WegoWise is able to identify top, average, and low performing buildings with the data they collect (Blaszczak, 2012). Recently, WegoWise has started using unexpected data results (e.g., unusually high water consumption for a building type) to identify opportunities for energy and water saving improvements in buildings (Connelly, Overview of WegoWise Tool, 2013).

In an interview with the President of New Ecology, the company that developed WegoWise, Ed Connelly stated that it could be possible to do a reasonably accurate assessment of building performance with a limited number of building characteristic inputs, but that this is contingent upon having access to energy data (Connelly, Personal interview with President of New Ecology, 2013). A fundamental component of creating a map which rates energy performance is disclosure of energy consumption data. Disclosure will be explored later on in the paper, but access to energy data is the single greatest barrier to understanding efficiency potential and creating meaningful energy maps.

Identifying potential data sources for conducting remote assessments is also important. If privacy is a concern, it would be best if the data used in any remote assessment is already publicly available to avoid litigation and the expense of paying for access to private data sets.

Data Sources for Remote Energy Assessments

Energy audits employ both operational data (i.e., energy use) and asset data (i.e., building characteristic). A remote energy assessment requires access to both types of data.

Operational data are energy use data. Typical energy audits require 12 months of historic energy use. This would include all applicable energy types such as electricity, natural gas, fuel oil, propane, and potentially others. Accessing operational data for a city-wide remote assessment, with the intention of creating an energy performance map of buildings, would most likely require a mandatory disclosure policy. Without mandatory disclosure, there would not be enough energy data to create a data rich energy map that offered meaningful information and insight, nor would there be enough data to conduct a remote assessment. Many barriers exist to accessing data and implementing a mandatory disclosure policy. However, if done correctly, increasing access to energy data could lead to significant transformations of the energy efficiency market through new tools – such as an energy map – and through enabling other energy innovations. Disclosure will be discussed in greater detail later on.

Asset data, which are building characteristics, are typically collected during an energy audit. However, some asset data are already available through publicly accessible tax assessor records. If tax assessor records are online, programs can be written to screen scrape information, making it available for use in remote assessment. While not as robust as an in-person data collection, tax assessor records can offer numerous valuable data points. For example, the Cambridge, Massachusetts, online Tax Assessor Database includes many relevant building characteristics, such as year built, property class, building type, gross square footage, heating type, heating fuel, and whether there is central air conditioning (City of Cambridge, 2013). A sample Cambridge tax assessor building entry can be seen in Figure 12. Other potential building asset sources include LiDAR data, which captures building heights. GIS records might also convey other parcel information.

15 Tremont St

Property Information:

Property Class:	THREE-FM-RES
State Class Code:	105
Zoning (Unofficial):	C-1
Map/Lot:	87-111
Land Area:	4,070

Property Value:

Year of Assessment:	2013	
Tax District:	R2	
Residential Exemption:	No	
Building Value:		$548,100
Land Value:		$263,100
Assessed Value:		$811,200
Sale Price:		$1
Book/Page:	39357/ 504	
Sale Date:	May 29, 2003	
Previous Assessed Value:		$797,200

Owner Information:

Owner(s):	BLUMSACK, DAVID E., TR. , THE 15 TREMONT REALTY TRUST P.O. BOX #45273 SOMERVILLE , MA 02145

Building Information:

Residential Building Number	**1**

EXTERIOR:

Style	OLD STYLE THREE FAM
Occupancy	THREE-FM-RES
Number of Stories	3
Exterior Wall Type	Frame-Clapbrd
Roof Type	Gable
Roof Material	Aspahlt Shingl

INTERIOR:

Living Area	3,531
Number of Units	3
Total Rooms	15
Bedrooms	6
Kitchens	3
Full Baths	3
Half Baths	0
Fireplaces	0

SYSTEMS:

Heat Type	Forced Air
Heat Fuel	Gas
Central A/C	N

CONDITION & GRADE:

Year Built	1916
Interior Condition	Good
Overall Condition	GOOD
Overall Grade	Good

PARKING:

Open Parking	0
Covered Parking	0

SUBAREAS:

Code	Description	Gross Area	Living Area
BAS	First Floor	1,177	1,177
FOP	Porch, Open	741	0
FUS	Upper Story, Finished	2,354	2,354
UBM	Basement	1,118	0
	Total	5,390	3,531

Figure 12 – Example of a publicly available tax assessor record for a multi-family building in Cambridge, Massachusetts (City of Cambridge, 2013).

Data challenges for remote assessment include incomplete information, inaccurate information, and obstacles to cross referencing different data sets. Figure 12 shows that while tax assessor records do offer considerable amounts of information, they currently do not offer as much information as an in-home audit. They do not identify whether the building has insulation, how old the heating system or boiler is, nor where there are air leaks, among other things. And this information can be vital for understanding building performance. For example, building systems, which include HVAC and hot water systems, can account for significant potential energy savings. Ed Connelly of New Ecology noted sometimes seeing 50% improvement in building performance from upgrading building systems alone. Electricity use can depend heavily on occupant behavior. Tax assessor records do not note the number of occupants nor uses within a building. For example, an apartment with a home office and many computers would likely be consuming more electricity than a similar apartment occupied by a traditional office worker (Connelly, Personal interview with President of New Ecology, 2013).

Moreover, the data in tax assessor records may not be accurate. Depending on when the latest assessment was conducted, information could be many years out of date or it could have been recorded incorrectly. In-home audits are able to verify building characteristic information and trained auditors are able to identify building features that a lay person may not recognize.

Another important challenge to note is the difficulty in correlating utility energy data with tax assessor records. Utility information is linked to meter number and assessing information is linked to parcels. Assessor information is different for residential properties, condominiums, and commercial properties because they are recorded by taxable entity. Utility addresses may not match tax assessor addresses, and utility meters do not necessarily associate with taxable entities. There are many-to-many relationships in which the entities of interest relate to one another in utility and city databases. Utility databases and tax assessor databases were not built with the intention of relating to each other, so it can be difficult to match records. Further confounding this problem is that buildings can have multiple meters and utility records do not indicate whether a meter is associated with a residential unit, common space, or perhaps a detached garage (Ferreira, 2013; Davis, 2013).

Existing Evaluations of Remote Energy Assessments

Conducting remote energy assessments is a relatively new phenomenon and there have not been many evaluations of the accuracy of different assessment methods. Primarily, evaluations of residential energy consumption models have examined top-down and bottom-up methods (Swan &

Ugursai, 2009; Kavgic & Mavrogianni, 2010), but these relate to aggregate energy implications, not individual building performance.

There are a few private firms employing remote assessment technologies, but their models and data are private. Retroficiency, as described earlier, uses 15-minute energy interval data to assess commercial buildings. They have a library of thousands of building models and they create a new model for each building they evaluate (Fisher, 2012). But Retroficiency's models and databases are not publicly available. The company's continued success suggests their models produce helpful assessments, but their accuracy has not quantified by an independent evaluator. Other energy firms attempting to conduct remote assessments have expressed skepticism of their own internal attempts at accurately identifying efficiency potential remotely.

The models developed by Zico Kolter and Joe Ferreira to predict building energy consumption in Cambridge, Massachusetts (these were used in the EnergyView map described earlier) employed data sets likely to be used in a remote energy assessment: utility-provided monthly energy data, tax assessor records, GIS information, and LIDAR data. Based on building characteristics they collected from these data sets, their models were able to account for about 75% of observed variance in energy consumption (Kolter & Ferreira, 2011). The remaining variance may potentially be explained by factors not recorded in the publicly available data sets, such as number of occupants and occupant behavior and preferences. The EnergyView model demonstrates the possibility of remotely assessing homes and suggests that as more data becomes available, the model's accuracy could improve.

Relative Energy Assessment Comparisons

Currently, due to incomplete and inaccurate data sets, it may not be possible to conduct highly accurate city-wide remote assessments. With the intention of creating a public energy map, it would be necessary to display assessments that people trust. If there is a significant amount of error in remote assessments, then the map will not be effective at motivating people to pursue energy efficiency. However, there are several methods for analyzing relative energy performance. These are not as detailed as full audits and cannot prescribe specific energy efficiency upgrades, but they do allow users to broadly compare the energy performance of different buildings. In order to be useful for map display, these relative performance assessments would need be easily understood (i.e., a lay person could quickly understand which buildings perform better and which perform worse), they would need to work across different residential building types, and their mandatory data points would need to be found on publicly available data sets like tax assessor records, with the assumption that utilities provide monthly energy consumption data. Potential assessment methods include Opower's model to compare similar buildings, the Department of Energy's Home Energy Yardstick, the Home Energy Rating System (HERS), and the Home Energy Saver.

Opower

Opower is an energy analytics firm focused on behavioral changes. They currently contract with more than 80 utilities to send personalized home energy reports to 15 million ratepayers. Homeowners receive the reports in the mail, which compare their homes' energy use to similar homes in their area. They are compared to the average home performance and efficient home performance in their neighborhood (Opower, 2012). A sample comparison report is shown in Figure 13.

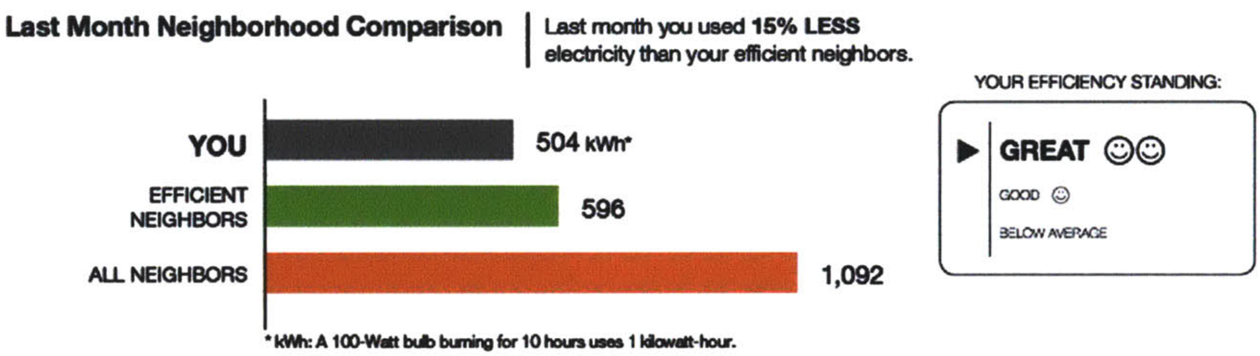


Figure 13 – Example electricity portion of a home energy report generated by Opower (Allcott, 2011).

Opower compares a household's energy use to a custom comparison group. The comparison group contains about 100 nearby houses that share similar characteristics, such as square footage and heating type (Allcott, 2011). If not enough similar homes are found, Opower loosens the constraints until they can build a big enough comparison group for their algorithms (Laskey & Kavazovic, 2011). If they are provided with hourly usage data, Opower's algorithms can disaggregate heating usage, cooling usage, and other loads (Laskey & Kavazovic, 2011). However, most of their analyses are conducted with monthly energy usage data which is collected approximately every 30 days by a meter reader. Opower contracts directly with utilities which provides them monthly meter data, program participation, rebate redemptions, and billing and account data (Opower, 2013). Opower does not publish how they collect the building characteristics, but they report that they source housing data, demographics, weather, and GIS data from third parties (Opower, 2013).

The strength of Opower's methods is in leveraging social norms to influence behavior. Households see their energy use relative to the mean of their comparison group (i.e., "all neighbors" in Figure 13) and to the 20th percentile of the comparison group (i.e., "efficient neighbors" in Figure 13). Their strategy has reportedly reduced energy consumption by 2.0% across participating households (Allcott, 2011).

A strategy similar to Opower's could potentially be used to generate relative performance ratings for residential buildings across a city and then color code those ratings for display in a map. Opower currently analyzes large data sets covering 15 million household which demonstrates that such a large analysis is possible. However, they display information only to utilities and individual households. If they are paying third parties for building characteristic and demographic information, it may not be possible to publicly display their results. Opower's algorithms are not published so it is uncertain whether they could be adjusted to leverage publicly available data. Moreover, it is unclear whether Opower's analysis covers all building types or what happens when individual buildings have incomplete data sets. While their method is promising, it is hard to say whether it could be applied to every residential building in a given geographic area.

Home Energy Yardstick

An Environmental Protection Agency program dedicated to helping consumers identify energy efficient products, Energy Star offers a quick online energy assessment through its tool called the Home Energy Yardstick. It ranks homes on a scale of 1 to 10 (10 being a better performer) by comparing them to similar homes. The average home scores a 5. The algorithm used accounts for local weather, home size, and number occupants. The Yardstick only collects the following data points from online users:

- Zip code
- Number of full-time occupants
- Square footage of home
- Select fuel types (electricity, natural gas, fuel oil, propane, kerosene, on-site coal, on-site wood)
- And 12-months' of energy data for selected fuel types (users have the option of uploading Green Button files if they are available for them or manually entering monthly data) (Energy Star, 2013).

Users receive a report (see Figure 14) which shows them their 1 to 10 rating on a ruler. The report also contains a graph of their monthly energy use and it disaggregates baseload from heating and cooling energy loads.

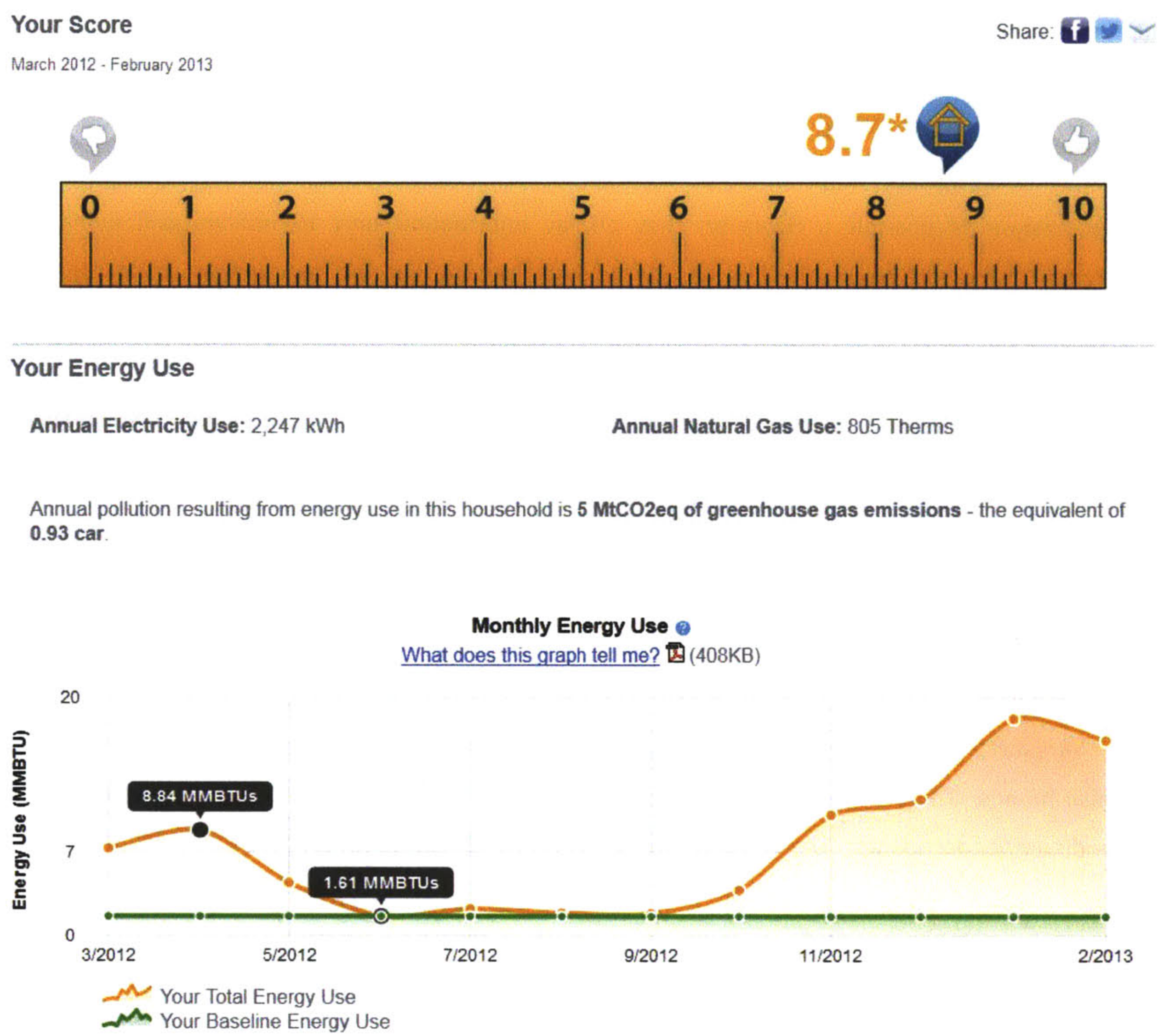


Figure 14 - Energy Star Home Energy Yardstick sample report (Energy Star, 2013).

The Home Energy Yardstick does not offer as comprehensive an assessment as an audit or as a more detailed self-audit online tool. However, for online users it quickly produces a relative benchmark for them to understand their household energy consumption. Also, by identifying heating load and cooling load, building owners may be able to understand opportunities for improving the energy performance of their buildings.

In terms of energy mapping, the Home Energy Yardstick is a promising relative assessment platform to consider. If utilities provide energy data, then it could be possible to collect square footage from tax assessor records. The output is easy to understand since people are used to scales of 1 to 10 and it would be possible to create a color scale for the Yardstick Score. However, challenges to using the Yardstick include not being able to remotely collect number of occupants and the inability to benchmark multifamily buildings with the tool. If the Yardstick's algorithms were modified to eliminate occupant data and to include multifamily buildings, this could be a potential candidate for conducting city-wide relative energy assessments.

Home Energy Rating System (HERS)

A home energy rating is an index which measures a home's energy performance. California has implemented a Home Energy Rating System to establish an energy score before energy implementing rebate-eligible efficiency upgrades. All homes are scored on a scale of 0 to 250, with 0 indicating the best energy performance for that type of building.

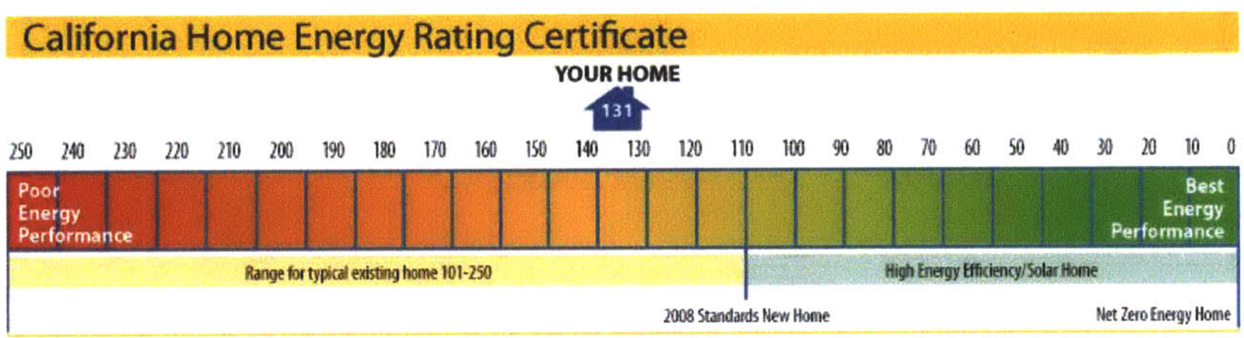


Figure 15 - California HERS scale (Center for Sustainable Energy California, 2013).

The California HERS demonstrates the ability to rate different home types on one scale and correlate that to a performance color, which would be suitable for mapping homes. However, this system requires a detailed in-home audit and would not be suitable for quickly assessing many buildings across large geographic areas. Moreover, the scoring system of HERS seems counterintuitive to other common rankings. A higher score indicates worse performance. This is opposite of the Home Energy Yardstick. A system such as this could be challenging for a mildly interested layperson to understand.

While HERS exemplifies a good color scale, it would not be practical for energy mapping applications nor conducting a city-wide remote assessment.

Home Energy Saver and SEED

The Home Energy Saver (HES) is a tool developed by Lawrence Berkeley National Laboratory for the U.S. Department of Energy. Homeowners are able to conduct a quick online assessment of their home by entering only zip code, address, year the house was built, number of occupants, and energy prices (estimated energy prices are prepopulated). With this information, HES provides an estimate of yearly energy costs, break down by type (e.g., heating, cooling, hot water, large appliances, small appliances, and lighting) and estimated energy costs if the homeowner upgrades the building (see Figure 16). Users have the option of submitting more details about square footage, air conditioning, refrigeration, and other things, to make the results more accurate (Lawrence Berkeley National Laboratory, 2013).

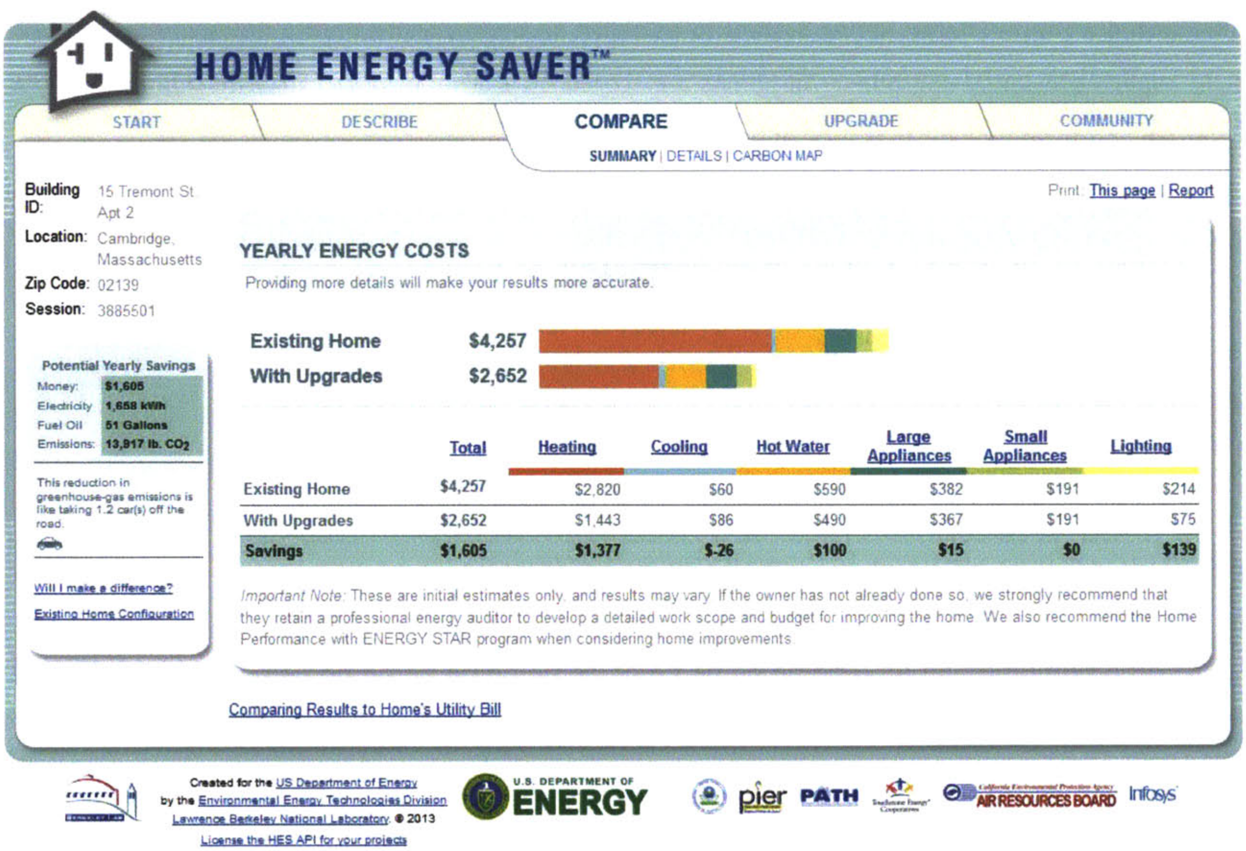


Figure 16 - Example of a Home Energy Saver report for a Boston-area home (Lawrence Berkeley National Laboratory, 2013).

This tool differs from Opower, Home Energy Yardstick, and HERS in a couple notable ways: 1) actual energy bills are not used, and 2) a comparative rating is not generated to indicate whether a home performs better or worse than a similar home. Moreover, this tool cannot assess multifamily buildings, though that functionality may eventually be incorporated (Lawrence Berkeley National Laboratory, 2012). It does complement an asset-rating system – Home Energy Scoring Tool – which provides a performance label, but that requires an in-home audit (Department of Energy, 2013).

HES thus lacks some of the advantages of other tools described, but it offers a comprehensive and standardized database on the backend – the SEED platform and Buildings Performance Database (Boston Green Ribbon Commission, 2012). An energy map which collects monthly energy data would need access to a database which stores the energy information and building characteristic information. This database would play an integral role in the development of the map and of other energy innovations. As a warehouse of information, it would enable other technological innovators to utilize the information for new innovations. And, such a database could cut down on costs of creating a map and provide a data platform for other energy innovations

The Standard Energy Efficiency Data (SEED) platform is software tool developed by the Department of Energy. SEED enables state and local governments to store and analyze large amounts of building and energy information. Users can automatically import data from the EPA Portfolio Manager and also export data to the Department of Energy's Buildings Performance Database (Department of Energy, 2012). SEED is free – so cities or states that decide to use it could significantly reduce their financial burden to build a platform that could store the data for an energy map. Moreover, since it is free and more agencies and organizations are likely to use it, it could end up providing the most common format for storing energy data. This means more innovations are likely to come from it and more cities would be wise to use it.

If HES could be combined with another DOE relative energy performance comparison, such as the Home Energy Yardstick, this could be a good option for cities or states considering the creation of an energy map. By using HES and thus entering data into SEED, the data is likely to be in a standard format and can be leveraged for other uses and innovations in the future. Moreover, this could significantly reduce the expense of developing a data storage mechanism for any participating municipality.

Lessons Learned on Remote and Relative Energy Assessments

From the evaluation of remote assessments and relative assessments, there are some key takeaways about using a remote and relative assessment in an energy map:

- If energy data is accessible, then it could be feasible to conduct a remote and relative energy assessment of most residential buildings in a given area.
- Use publicly available data for building characteristics in any assessment. These will likely come from tax assessor records, GIS records, and LiDAR scans if available. Using publicly available data avoids potential privacy complaints and eliminates the need of purchasing access to private data sets.
- Utility energy databases and city databases are difficult to cross reference. Rectifying the databases may be time intensive.
- Use a remote and relative assessment system which is simple to understand by the general public and facilitates color coding of building performance which would appear on maps.
- Use the Standard Energy Efficiency Data (SEED) platform created by the Department of Energy to store and manage energy data across jurisdictions. This will save the cost of developing individual platforms in different municipalities and help to standardize energy data taxonomy.
- The Home Energy Yardstick is a promising choice for a remote and relative energy assessment system. If it can be adjusted to calculate a performance rating without requiring occupancy data, all it's other inputs can be gathered remotely or from utility energy data. Moreover, it is an Energy Star product and Energy Star is a trusted label. And it produces an easy to understand score on a 1 to 10 scale which could easily be converted to a red-to-green color ramp for an online map.

Chapter 5 – Data Transparency and Disclosure

Access to energy data is the greatest obstacle to conducting citywide remote and relative energy assessments. Establishing clear pathways to energy data is necessary to conduct these energy assessments and to create an energy map. Across the United States, an increasing number of cities are implementing energy disclosure policies which are making more energy consumption data publicly available.

This chapter examines privacy and data access as it relates to energy consumption data. It explores data access trends in the energy field, existing disclosure policies, and potential obstacles to data disclosure which include the aforementioned privacy concerns as well as structural barriers to compliance.

While mapping technologies are more and more prevalent in other areas (e.g., the ubiquity of Google Maps, the location of restaurants on Yelp, and the geolocation of photos taken with smart phones), energy efficiency has lagged behind other industries in leveraging the power of maps. However, it is not the lack of technological capability which limits the development of energy maps. Limited access to energy data is stunting progress in the energy efficiency world. As Bennett Fisher, CEO of Retroficiency said, "The problem is not good tools to analyze data, the problem is getting access to data," (Fisher, 2012).

Data access continues to be the greatest barrier to creating energy maps. Utilities are reluctant to make energy data available. The perceived reasons for utility reticence to share data range from the belief that utilities fear potential litigation and without a government mandate will not willingly release data (Blasnik, 2013) to the view that utilities are holding onto data because they understand that it is an increasingly valuable commodity and will try to sell the information in the future (Davis, 2013). The most cited reason is concern for ratepayer privacy.

If data were to become more available, the prevalence of energy maps would increase and they would bring greater visibility to the field and possibly help to transform the market. Improving data access is necessary to take the transformative steps. There are current efforts to open up access to energy data. One of these is an industry led effort called the Green Button Initiative which makes it easier for ratepayers to assign their data to third parties. A small number of U.S. cities have implemented mandatory energy disclosure policies, though most of these do not address residential energy consumption data.

Green Button Initiative

Federal recognition of the importance of energy data galvanized the creation of the Green Button Initiative, an industry-led effort to improve availability of energy data. Sparked by a challenge in September 2011 from then U.S. Chief Technology Officer Aneesh Chopra to give customers greater access to their energy data, industry stakeholders worked together to officially launch the program in January 2012 (White House Office of Science and Technology Policy, 2012). This voluntary program encourages utilities to release personal energy data to customers in a standard format as an XML file (EnerNex). As of October, 2012, 29 utilities have committed to the Green Button Initiative (see Figure 17). This amounts to 40 million residential customers gaining digital access to their energy data (Innovation Electricity Efficiency, 2012).

Utility	State	Customers
Implemented		
Pacific Gas & Electric Company	CA	4,570,000
San Diego Gas & Electric	CA	1,230,000
NSTAR	MA	790,000
Smart Meter Texas (Oncor, CenterPoint, AEP)	TX	5,230,000
Reliant	TX	N/A - Retailer
TXU Energy	TX	N/A - Retailer
Committed		
Southern California Edison	CA	4,270,000
Glendale Water and Power	CA	70,000
PacifiCorp	CA, ID, OR, UT, WA, WY	1,470,000
United Illuminating Company	CT	324,000
Northeast Utilities	CT, MA, NH	3,090,000
Pepco Holdings Inc.	DC, DE, MD, NJ	1,560,000
JEA	FL	430,000
Sawnee Electric Membership Corporation	GA	150,000
Kootenai Electric Cooperative	ID	3,000
Commonwealth Edison	IL	3,430,000
American Electric Power	IN, LA, MI, OH, OK, VA, WV	3,650,000
National Grid	MA, NH, NY, RI	2,730,000
Baltimore Gas and Electric	MD	1,010,000
Bangor Hydro Electric Company	ME	117,000
Central Maine Power	ME	620,000
Virginia Dominion Power	NC, VA	2,160,000
Consolidated Edison*	NY	2,500
Portland General Electric	OR	720,000
PPL	PA	910,000
PECO	PA	1,400,000
Chattanooga EPB	TN	140,000
Austin Energy	TX	370,000
Efficiency Vermont	VT	330,000
Total		**40,446,500**

*Consolidated Edison will initially offer Green Button to 2,500 large building owners.

Figure 17 - A list of utilities nationwide that have voluntarily committed to the Green Button Initiative as of October 2012 (Innovation Electricity Efficiency, 2012, p. 3).

NSTAR has implemented Green Button functionality and information can be downloaded as a CSV or XML file. The file includes the associated address, the start and end dates of 12 previous billing periods, the KWH usage for each period, and the cost ($) for each period (see Figure 18).

Energy Usage Information			
For location:	15 TREMONT STREET CAMBRIDGE MA 02139		
Data for period starting/ending:	11/25/2011	12/22/2012	
Current billing period as of:	12/22/2012		
Time period (start)	Time period (end)	Usage (KWH)	Cost of Usage
11/26/2012	12/22/2012	185	$31.93
10/25/2012	11/26/2012	210	$35.34
9/25/2012	10/25/2012	148	$26.93
8/24/2012	9/25/2012	165	$29.22
7/26/2012	8/24/2012	228	$37.77
6/23/2012	7/26/2012	243	$40.28
5/25/2012	6/23/2012	121	$24.38
4/25/2012	5/25/2012	123	$24.71
3/24/2012	4/25/2012	159	$29.93
2/27/2012	3/24/2012	146	$28.04
1/26/2012	2/27/2012	209	$37.17
12/27/2011	1/26/2012	212	$37.44
11/25/2011	12/27/2011	178	$31.45

Figure 18 - Sample information in a CSV file from NSTAR's Green Button download.

A one-year review of the Green Button Initiative conducted by IEE noted the numerous benefits that could come from standardizing energy data formats and increasing personal access to energy data. They pointed to the likely increase in innovative apps developed as a national standardized data format is adopted. They suggest that by standardizing the data, there will be a lower barrier to entry, "[e]liminating this barrier to entry for software developers is a proven approach for developing a thriving developer ecosystem…" (Innovation Electricity Efficiency, 2012, p. 6). They also note that standardizing data facilitates innovation by reducing time spent on collecting and cleaning data across utilities. "Developers can focus on creating analytic tools based on a common data platform rather than expending resources on conforming to different data formats. Standards also provide long-term certainty, a condition that supports investments in new ideas," (Innovation Electricity Efficiency, 2012, p. 6).

The Green Button Initiative is a good step forward in making data more accessible. The program is looking to improve access even more by implementing Green Button Connect which will enable ratepayers through a single click to push data to third parties instead of downloading the data files and uploading them to the third party sites (Innovation Electricity Efficiency, 2012). However, a more transformative measure is needed to significantly impact the energy efficiency market. While Green Button allows individual to access their information, public disclosure would further enhance the benefits noted by IEE – there would be increased innovation among software developers and others. Furthermore, public disclosure may have the added benefit of exerting social pressure on high consumers to lower the use. The ability to develop an energy consumption map using publicly disclosed data would be another benefit.

Disclosure Policies

There are two types of disclosure, an asset (building) disclosure and operational (energy) disclosure and different disclosure ordinances utilize these in different ways. For an energy map, operational disclosure (energy data) is the most integral. Building data could perhaps be gleaned from tax assessor records or other means. For the policies that have been implemented, disclosure happens at different times or triggers – sometimes at time of home sale, at time of listing, at the closing date, or on a regular schedule regardless of sale transaction (Cluett & Amann, 2013). A small number of U.S. cities have implemented energy disclosure policies, including New York City, Seattle, San Francisco, Austin, and Washington, D.C. (Boston Green Ribbon Commission, 2012). Locally, Boston proposed a Building Energy Reporting and Disclosure Ordinance to the City Council in February 2013 which passed in May 2013 (City of Boston, 2013) and Cambridge, Massachusetts, is considering implementing a similar policy.

However, Boston's disclosure ordinance would only apply to residential buildings with more than 35 units (City of Boston, 2013). Across the country, most disclosure policies similarly only apply to commercial or large multi-family buildings. As of April 2013, there were 14 residential energy use disclosure policies in place in the United States (Cluett & Amann, 2013). Most of these apply to buildings 10,000 square feet or greater. As threshold square footage for participation declines, disclosure programs become more complex. More building owners are required to participate and many of these are small property owners which may lack the resources that larger property firms possess (Boston Green Ribbon Commission, 2012).

In an interview with Meghan Shaw, Community Outreach Director of the Cambridge Energy Alliance, she noted that the administrative complexity of mandating energy disclosure of small buildings perhaps outweighed the benefit. She explained that in Cambridge, Massachusetts, there are fewer than 200 property owners which own 91% of commercial property space in the city (Class A and Class B spaces). Her opinion was that once smaller spaces were regulated, many more people would be required to participate – which would require much more administrative support – but not actually capture much more building area (Shaw, 2013). However, residential buildings – which would be largely left out of disclosure policies aimed at buildings greater than 10,000 square feet – account for 35% of end-use energy efficiency potential (McKinsey Global Energy and Materials, 2009), suggesting that if efficiently administered even smaller residential buildings could benefit from energy disclosure policies.

To be most effective, a disclosure policy should apply to all residential buildings and the disclosed energy data should come from the utility to reduce the burden of compliance on building owners. Instead of requiring individual property owners to submit their energy data to cities, the utilities could be required to provide it. If thinking about an energy map, monthly energy updates would be idea. However, annual updates would keep the data fresh and relevant. To address concerns of privacy, utilities could offer an opt-out option, enabling ratepayers to voluntarily withdraw their energy data from the public disclosure program.

Obstacles to Disclosure

Energy disclosure would prime the energy efficiency market for transformation through increased data analysis and innovation. An energy map built using the disclosed energy data would enable homebuyers and renters to make more informed decisions. However, energy disclosure, especially for residential buildings faces many barriers. Among them are privacy concerns and the ability to ensure compliance. Both of these could be addressed by requiring utilities to disclose energy data to cities on a no-more-than-monthly basis and by allowing residential ratepayers to opt-out of disclosure if they desired.

Privacy Concerns

Due to privacy concerns, among other reasons, utilities have been reluctant to release ratepayer consumption data. Many of the privacy concerns about energy data are linked to the growing implementation of smart meters. Thirty-seven million smart meters have been installed in the U.S. as of 2011 (U.S. Energy Information Administration, 2013). Smart meters can produce highly granular data which some fear could compromise the safety of residents by enabling nefarious third parties to parse out their living patterns and discover when they are not home, leaving them ripe for burglary or other crimes (Nunez, 2012). The DOE has noted that smart meters, "...could reveal personal details about the lives of consumers, such as their daily schedules (including times when they are at or away from home or asleep), whether their homes are equipped with alarm systems, whether they own expensive electronic equipment such as plasma TVs, and whether they use certain types of medical equipment," (Department of Energy, 2010, p. 2).

However, privacy concerns such as these could be assuaged by releasing data at the appropriate granularity so that residents would not feel their personal safety is compromised. Firstly, data could be publicly released on a monthly basis. This would prevent detection of daily energy patterns which might indicate when homes are occupied and when they are empty. Moreover, most residences do not have smart meters, but analog meters which still require a manual reading to record energy consumption. For these meters, monthly data is the most granular level available. And, an energy map would not need finer data than every month and could even be successfully built if energy updates only came quarterly or yearly. Also, in multi-tenant buildings, energy data could be aggregated to protect the privacy of individual units.

Moreover, an opt-out policy could be implemented with any residential energy disclosure law. This enables individual ratepayers to choose to not have their information released. If any individual still felt nervous about their privacy or safety, he or she could choose to withdraw their information from the public database. Ryan Davis of Energy IT noted that the Gainesville Green energy map has an opt-out policy, but that very few people have chosen to take down their information (Davis, 2013).

Compliance with Disclosure

There can be significant costs associated with implementing an energy disclosure mandate. The Boston Green Ribbon Commission conducted a survey of existing disclosure programs to research the potential impact of creating one for Boston. Some of their main findings suggested that the administrative costs and database costs of such programs can be large. They found that disclosure programs generally required at least one full-time employee to provide support to building owners and manage implementation. One program estimated that just implementing the energy disclosure program cost $500,000 (Boston Green Ribbon Commission, 2012).

Furthermore, data management can add significant expenses. The Green Ribbon Commission also reported that one city's software development costs were between $75,000 and $100,000 dollars (Boston Green Ribbon Commission, 2012). Staff and software expenses associated with disclosures could be prohibitively expensive for some jurisdictions.

Again, mandates focused on utility disclosure could mitigate some of these costs. If only the utility is obligated to provide energy data, instead of thousands of property owners submitting it individually, a city could cut down on staff hours devoted to technical support. And cities could leverage free government software and databases like SEED to defray the cost of software development.

The Future of Energy Disclosure

Although there are obstacles to implementing energy disclosure, there is a movement to increase access to energy data. Boston's energy disclosure policy which passed in May 2013 is the latest example of a city taking steps to make energy information more available. While privacy may continue to be a concern for some, the experience of Energy IT with their online energy maps suggests that only a small number of people would opt-out of participating. With more and more personal data being collected on a daily basis through things like cell phone use, internet searches, and credit card purchases, people may become less concerned with sharing energy information. There is a general trend to make energy data publicly available because of the potential energy benefits. There is reason to be optimistic that energy disclosure ordinances will only increase in the United States.

Chapter 6 – Recommendations for Accessing Data and Creating a Residential Energy Map

This chapter lays out the recommendations for State-led energy disclosure policies, how the Federal government could support such initiatives, and explains what components would make an effective energy map.

Energy data will be at the heart of many energy efficiency projects in the future. As smart technologies roll out, smart meters will collect granular data on residential energy consumption. Smart appliances and lights will signal their minute-to-minute consumption giving homeowners greater control of energy consumption, even when they are away from home. This plethora of energy data will foster new innovations and hopefully make huge strides in energy efficiency achievements. The energy map is one such new technology which could leverage energy data to encourage energy efficiency upgrades. Currently though, energy data is held by utilities and for the most part is not made publicly available. This stifles innovation and prevents critical decision makers – homebuyers, renters, and property owners – from seeing that information and making active decisions based on it.

Energy information has the power to transform the energy efficiency market, beyond even the applications of mapping. Information presented to the right people at the right time can increase interest in energy efficiency. An energy map which displays energy consumption and relative energy performance of buildings can influence people to improve their buildings or to rent a more efficient apartment over a less efficient apartment. An energy map could enable energy agencies to identify neighborhoods and buildings for efficiency outreach. If energy map information was integrated into existing real estate maps such as Walk Score, Zillow, Trulia, or Craigslist, then building energy information would be provided in at a time when people are deliberately thinking about housing decisions and could have an even greater impact.

But, in order to develop and effective energy map, there will need to be mandated energy disclosures instituted across states and cities. Climate change, the growing cost of energy, and grid instability are all reasons why utilities should be obligated to disclose building-level energy consumption data. The rest of the chapter elucidates the potential impacts of an energy map, how energy disclosure should occur, and how energy data should be presented in a map for the most effective outcomes.

Energy Map Impacts

By publicly disclosing energy consumption and an energy performance rating in an online energy map, energy efficiency will be positively impacted through improved decision making and establishing new social norms.

Having access to energy consumption data online will enable renters to choose rental units which consume less energy and cost them less money. If landlords notice that they have a harder time attracting or retaining tenants because of their building's poor energy performance, they will be more likely to upgrade their buildings. Meghan Shaw at the Cambridge Energy Alliance was skeptical of the impact of public energy disclosure in Cambridge, Massachusetts, because it is a tight rental market. Since there are a steady stream of students to the many nearby universities, landlords face very low occupancy rates. However, in other markets with higher vacancy rates, an energy map could help renters make more informed decisions and ultimately influence landlords' willingness to invest in upgrades. Moreover, the map would still be helpful to homebuyers who would be able to incorporate the value of energy performance into their home buying decisions.

The energy map could also improve energy efficiency performance through social norms. A three-year study conducted in San Diego by Robert Cialdini and Wesley Schultz showed that descriptive normative information had greater impact on household's energy conservation measures than information on saving money, helping the environment, or social responsibility. They had previously conducted a study that showed people were more likely to reuse hotel towels when told other guests were reusing hotel towels and wanted to research whether this could be repeated for energy conservation measures. Their results showed that descriptive norms – when people learned that their neighbors were using fans instead of air conditioners – made more significant changes to consumers' energy behaviors than other factors (Cialdini & Schultz, 2004).

Descriptive normative information is relevant to the proposed residential energy map. A color coding scheme – likely red to green for bad to good performers – conveys normative information about other buildings. Neighbors may see that they perform worse than their neighbors and make efforts to improve. Or property owners may notice their portfolio of buildings does not perform as well as other properties and may feel pressure to improve their performance. The map is in essence displaying descriptive normative information across a city.

Data Disclosure and Data Management Platforms

Although the impact and potential for a residential energy map are great, there are many obstacles to making an energy map a reality. These challenges include energy data access, privacy concerns, compliance with potential mandated disclosure laws, ensuring residential buildings are included in mandated disclosure, and using a standardized taxonomy and database for energy information across jurisdictions. However, many of these could concerns could be addressed through effectively implemented state energy disclosure mandates that targets utilities for compliance – not individual building owners. The disclosure policies should establish appropriate opt-out measures to address privacy concerns of any individual residential ratepayers and requires energy disclosure of all building types. The Federal government could support disclosure efforts by recommending a standard energy database for use across jurisdictions, suggesting a pathway to facilitate cross-reference multiple city-level databases, and providing research and funding to disclosure efforts.

1. States mandate that utilities disclose energy use of all customers

Since states regulate utilities, states should mandate disclosure of all building-level energy consumption data. Moreover, disclosure policies should require utilities to disclose the information, not individual building owners. Reviews of existing disclosure policies which require building owners to release information to cities put an undue burden on cities and on building owners. Cities needed to hire personnel to enforce compliance and offer technical support which added to their operating budgets. Moreover, when building owners are required to disclose the information, building owners may need to collect energy information from multiple tenants, which may be burdensome, especially for small property owners. These obstacles can be bypassed by collecting information directly from the utility. Instead of requiring collection from thousands or tens of thousands of building owners, information could be collected from one or a few sources, the utilities.

2. The Federal government recommends using one software and database platform across jurisdictions

The Federal government should recommend one database to be used across states which will receive the disclosed information and the platform which will make the information accessible to cities, states, entrepreneurs, and other parties. This will likely be the Department of Energy's Building Performance Database and the Standard Energy Efficiency Database (SEED) platform. The cost of developing an energy and building database can be enormous; one municipality reported spending around $100,000 on the project (Boston Green Ribbon Commission, 2012). The DOE has built its own database, the Buildings Performance Database, which integrates with SEED, their standardized software and taxonomy for collecting energy information. Using these platforms lowers the cost for states and cities making it more likely that compliance with mandated disclosure would be successful across the country. An another benefit is that entrepreneurs would face lower barriers when developing new technologies because they would know energy data would be accessible in the same format on the same platform across the country. Furthermore, using a DOE database would facilitate potentially using the Home Energy Yardstick as the remote assessment tool for conducting remote and relative citywide residential buildings assessments.

3. With Federal support, cities and utilities create pathways for correctly cross referencing multiple databases

Currently, utilities and cities do not necessarily use the same master address file which means it can be difficult to correlate a meter to a specific building. Cross-referencing multiple databases such as energy records and tax assessor records, which is necessary for remote energy assessments, can sometimes result in many records going unmatched. There have been other efforts recently to standardize relevant city information across agencies, for example 3-1-1 and 9-1-1 efforts have led to the use master address files in some cities. Master address files could similarly benefit utilities which would be able to correctly cross-reference meters to physical addresses used by cities. This would make geocoding information easier in the long run. When suggesting a database for disclosure, the Federal government could suggest modifications to the Buildings Performance Database which would facilitate correlating different city databases, for example the database could include a field for master address IDs. Furthermore, if utilities added a field to record use for each meter, such as whether it was in-unit, for a common area, or for a detached garage, then subsequent energy analyses could be performed with greater ease.

4. States require only monthly energy updates and include opt-out policies in their disclosure laws to address privacy concerns

Mandated energy disclosure will cause some building owners to protest due to privacy or safety concerns. One common safety concern is that if real-time energy data is publicly disclosed then it may be possible to tell when buildings are unoccupied leaving them vulnerable to theft. Other concerns include individuals or organizations simply wanting to keep their energy data private. In their energy disclosure policies, states could address the safety issue by requiring disclosure no more often than on a monthly basis so that real-time information remains private. Initial disclosure requirements could focus on multi-tenant buildings where information could be aggregated to protect privacy and where there may be support among tenant's rights groups to give renters more information about units they lease. Finally, residential disclosure should come with an opt-out policy so that individual ratepayers could decide to withdraw their information from the public program.

5. States require energy disclosure for all building sizes

By releasing energy data from all residential and commercial buildings, more people would benefit from increased data access, more building owners may pursue energy efficiency upgrades, and more entrepreneurs will be able to use the data to develop energy innovations. Because compliance with disclosure may be a problem for small building owners who lack resources, utilities should be required to provide building aggregated data to the city.

Moreover, disclosing data for all buildings would include multi-family buildings, where perhaps many of the occupants are renters. Utility expenses can significantly increase a household's budget and these are frequently unknown when renters sign leases. Renters are more likely than homeowners to be low-income and so face greater hardship from high electricity and heating bills. If multi-family energy data is publicly disclosed, renters can make more informed housing decisions which would help them to minimize expenses.

Besides social benefits, the environmental benefits of the disclosure policy will be greater if all buildings are included in the policy. One impact of disclosure is that building owners may implement efficiency upgrades to attract tenants or to market their buildings as being "greener" than other buildings. These efficiency upgrades could result in significant CO_2 emissions reductions. Energy disclosure of smaller buildings would encourage more owners to implement energy efficiency measures and thus increase the environmental benefits of the policy. Moreover, when people are searching for housing they search across building types. People hunting for homes may consider single-family homes, apartments, and condos when making their decision. Energy disclosure will have maximum impact on their energy perceptions if all building types are included.

Finally, energy data disclosure will spawn technological and service advancements which could encourage energy efficiency. For example, energy efficiency firms could use the data to identify neighborhoods with significant efficiency potential and do outreach campaigns there. If all buildings are included in the disclosure policy, the deeper data set will foster more robust analysis and innovation.

6. State energy disclosure laws require that information be made publicly available via an online map

To maximize the positive benefits of disclosing energy data, the states should require that data be made available on an online energy map that displays total monthly consumption and a relative energy performance score. An online map is an ideal platform for many reasons. People are familiar with using online maps, so the technology will be familiar to them. Moreover, a map can visualize the information in a way that is easier to understand than simply providing all the information in a spreadsheet. And an energy map will have more of an impact on energy efficiency. This could happen in a few different ways. First, publicly displaying energy information on a map may create new social norms and exert pressure on high energy consumers to reduce their energy use. Second, homebuyers and renters may choose to buy/rent homes with better energy performance records thereby encouraging building owners to invest in upgrades. Finally, the map could help utilities, contractors, energy non-profits, and energy efficiency firms identify buildings that would benefit most from energy efficiency upgrades.

Energy Map Components

When energy data is available, an energy map could be made which would impact energy efficiency by allowing homebuyers and renters to seek out higher performing buildings, creating new social norms which pressure property owners to upgrade their buildings, and enabling energy agencies and firms to target individual buildings and neighborhoods which consume excess energy. Previous EESP research also noted that an effective energy map should have three components: 1) An information display that combines energy data with other relevant data sources such as GIS and tax assessor records; 2) Affiliated programs and incentives which inspire users, professionals, or community groups to take action; and 3) A feedback input option which enables energy suppliers to receive augmented data such as age of appliances in homes (Reul & Michaels, 2012). This section builds on those findings to suggest more specific energy map components. These components should be included in energy maps required by state energy disclosure laws.

Residential energy information should be displayed in an interactive map where online users could view gross monthly electricity and gas bills as well as view a standardized energy performance rating for single-family homes and multifamily buildings. Buildings could be color-coded for relative energy performance compared to similar buildings in the area (e.g. red is a high energy user, yellow is moderate, and green is low). Building an interactive map would help prospective renters identify high energy consuming apartments and help prospective buyers choose more energy efficient buildings. An energy map would create social incentives for landlords and homeowners to upgrade their buildings. Moreover, other interested parties such as government agencies and energy contractors could use the map to target neighborhoods for energy efficiency outreach.

A relative energy performance score which is easily understood and can be color-coded for map display should be used. This assessment system must rely on publicly available data to determine building characteristics. While not as detailed as an in-home audit, a remote assessment could provide useful information to renters and homeowners. The Department of Energy's Home Energy Yardstick could be a good candidate for a preliminary assessment system, but as more data becomes available, more complex systems could be utilized.

Based on research collected and discussed earlier in this paper, I expand on previous EESP research and propose specific features for a functional energy map which could catalyze change in the energy efficiency market.

An effective Energy Map:

1. Displays data at a building level. For multi-family buildings, the information displayed could be an average for all the units
2. Displays gross consumption and an energy performance rating
3. Uses a relative energy performance rating which can be applied to across residential building types
4. Enables customizable information displays for different audiences. Both lay people and policymakers or energy specialists should be able to use the map
5. Updates energy data regularly, ideally every month
6. Allows people to opt-out of having their information on the map
7. Connects users to other websites and services for energy efficiency
8. Facilitates energy competitions and customized building comparisons
9. Is accompanied by a marketing campaign to raise awareness of the map and its functions
10. Accesses data from a database which provides a standardized taxonomy like SEED
11. And has an API which enables it to be embedded on other sites such as Trulia or Craigslist

1. Display data at a building level

Many energy maps exist which aggregate energy data to a block level, such as the Los Angeles Electricity Consumption Map or the New York City Building Energy Map. However, these maps have more impact on energy professionals and policymakers than on buildings owners who make building performance decisions or on homeowners and renters who are deciding where to live. An energy map must display energy consumption at a building level for it to impact the decisions of empowered homebuyers, renters, landlords, and property owners. Without the ability to understand individual building performance, energy maps will have limited impact on energy efficiency.

2. Display gross consumption and a relative energy performance rating

Homeowners and renters are more interested in their energy bills than in kilowatt-hours/square foot or carbon savings. They are keen to know what their energy will cost them each month. Showing high energy bills may have more of an impact on this audience than other measurements. However, displaying a relative energy performance rating on a map will help users to understand which buildings are performing optimally and which are performing poorly. They can evaluate which buildings have potential to improve and which are already performing optimally. Map users should have the option of seeing gross monthly energy consumption and a relative energy performance score.

3. Use a performance rating which can be applied across residential building types

An energy map targeted at the residential market should use a standardized relative energy assessment rating system which can be applied to all building types. Prospective buyers and tenants search for residences across building types. They may consider single family homes, condos, and apartments. This means whatever rating displayed on the map should be able to be applied to many building types and exhibit a consistent a score. It should also utilize publicly available data to conduct scoring. If able to handle multi-family buildings, the Home Energy Yardstick may be good options for a relative assessment tool which can conduct analyses remotely.

4. Display different information for different audiences

The map should have the ability to toggle between different analyses. As Ryan Davis of EnergyIT noted, homeowners and renters are more interested in gross energy bills, but policymakers and energy analysts are interested in energy use intensity or an energy performance rating. Users should be able to select between different types of information that are most relevant to them.

5. Regularly update energy data, ideally every month

To keep the energy information fresh, the energy data should be updated regularly. Every month would be ideal and monthly updates could minimize some of the concerns of privacy by not permitting real-time energy updates from smart meters. If monthly updates are not feasible, quarterly updates would be reasonable and would capture seasonal a changes. However, energy updates to the map should occur no less than annually to keep the information fresh for users.

6. Include an opt-out policy so building owners could exclude their buildings from the map

Individual building owners should have the option of opt-outing of having their information used in the map. This would give users concerned about privacy control over whether or not they participate. The Gainesville Green Map has an opt-out option and only a small number of residents have elected to opt-out.

7. Connect users to meaningful energy efficiency incentives, rebates, and services

Since this map is meant to impact the energy efficiency market it should also link to relevant rebates and state- or city-programs which help residents and building owners improve their energy performance. The rating system employed to rate buildings is unlikely to be prescriptive about what can actually be done with in a particular building, but directing users to other agencies will help them to take the next steps in improving their homes.

8. Facilitate competitions and building-to-building comparisons

The energy map could be leveraged to incentivize people to improve their buildings in different ways. Energy competitions could encourage people to take steps to reduce their energy consumption. The map should be able to facilitate custom groupings and comparisons so that functions, such as energy efficiency competitions, could run off the platform.

9. Promote the map through a marketing campaign to raise awareness

A marketing campaign should accompany any development and launch of an energy map. Perhaps it could accompany a community-based social marketing effort or another outreach campaign. However, for the map to be effective, people need to be aware it exists. City and state resources should be devoted to promoting and distributing the map.

10. Access data from a database which provides a standardized taxonomy like SEED

As cities develop their own energy maps, they should use a standardized platform and database to store their energy and building data information. The Federal government should encourage local governments to use SEED and the Buildings Performance Database. This has multiple benefits. It reduces the cost to local agencies of developing a map or implementing a disclosure mandate. And it provides a standardized taxonomy that future innovators may use to develop new energy tools.

11. Have an API to deploy the information in other websites and online maps

The map should be developed with an API so that the information could be displayed on other real estate related sites such as Trulia, Walkscore, Zillow, and Craigslist. People are beginning to understand the value of energy efficiency and so other websites will be interested in incorporating information from the residential energy map on their sites and maps.

Chapter 7 – Conclusion

A residential energy map has the potential to change the energy efficiency market. Energy is a transparent and confusing issue for many people. By visually representing energy consumption spatially in a map, people will more closely engage with the information and make decisions using it. And there is a unique opportunity to integrate energy data into maps dealing with real estate. This connection would increase the likelihood that energy performance be valued in housing and would have the potential to influence decisions made by homebuyers and renters.

Online maps are already frequently used when people make housing decisions through websites like Walk Score, Craigslist, and Zillow. If energy consumption and relative energy performance could be integrated into maps likes these, people would be receiving critical energy information at the moment they make housing decisions. Right now, energy use is unseen and unknown to many people, but placing it on a map would bring it to the surface and potentially at the moment when it would influence their housing decisions. Renters may choose to move to a more efficient, less costly apartment. Homebuyers may choose to purchase a more efficient home. And property owners may choose to upgrade their buildings when they notice their buildings perform worse than their neighbor's building and they are losing prospective buyers or renters to "greener" properties.

Energy maps will become more prevalent as more energy and building characteristic data becomes available. Although there has been some resistance to publicly disclosing energy data, this is not likely to prevent energy data from becoming available in the long run. More and more personal information is being recorded and detailed property information, such as assessed property value, is already publicly available. Disclosure policies like BERDO, which recently passed in Boston, are opening the doors to rich energy data sets and this trend of making more data publicly available will continue. A Federal recommendation to disclose energy data could catalyze improved access to data and catalyze the onset of the benefits that result.

Furthermore, technological advances will diminish the transaction costs of collecting and correlating building characteristic information from databases such as tax assessor records to energy information. This means remote energy assessments will become less costly to do. Data sets will likely become more rich and accurate if energy performance information becomes highly valued. For example, tax assessor records may change to incorporate new data points which relate to energy consumption features. Remote and relative energy assessments will become easier, cheaper, and more accurate. Displaying the results of remote assessments in a map will demand that people pay more attention to energy efficiency. And as richer data sets become available, these remote assessments will become more accurate and specific, suggesting that in the longer term this may also reduce the need for an in-home audit.

As energy data comes online, which will inevitably happen, more innovative approaches to managing and reducing energy consumption will appear. The promise of rich data sets will encourage entrepreneurs and innovators to develop new applications and technologies to monitor and reduce energy use. Smart meters will continue to roll out and individual households will have the ability to analyze their own energy use at an incredibly granular level. Homeowners will be able to communicate with smart appliances which are recording and relaying their own energy consumption. Sophisticated energy management strategies will be employed by individuals, businesses, utilities, cities, and states.

Fundamentally, as more energy data becomes available, the more we will understand where efficiency potential can be found in our homes, businesses, and cities. Greater information access will lead to a more efficient use of resources and a better valuation of energy efficiency measures. Energy efficiency will be central to securing clean and reliable energy systems across the United States.

As carbon dioxide levels continue to increase and we feel the impacts of climate change through dramatic weather events like Hurricane Sandy, increased attention must be paid to aggressively and dramatically diminishing our dependence on fossil fuels. Bold steps will need to be taken and the sooner we take action, the better off we will be. Making changes like mandating energy disclosure and fostering the development of an energy map may seem small, but they will set the stage for greater changes and more meaningful impacts which will bring us closer to a more stable, cleaner energy future.

Appendix A – Interviews

Interview	Key Points
Michael Blasnik Principal Michael Blasnik Associates Data Remote assessments For-profit organization	The best predicter of a heating bill is the previous year's bill. Electricity consumption is much less dependent on building type. Residents are not interested in normalized data, they just want to see what their energy costs will be. An energy map could show gross heat use, building size, and year built. Energy data privacy is absurd, there should be a legal mandate that utilities release information.
Ed Connelly President New Ecology www.newecology.org Data Remote assessments Multifamily buildings Non-profit organization	Gas consumption is closer to an asset rating while electricity use is largely determined by occupant behavior. If energy data is available, it might be possible to do a remote energy assessment. However, building systems significantly impact performance and these cannot be known without going into a building.
Ryan Davis Director of Programming Energy IT www.energyit.com Data Energy mapping For-profit organization	In an online residential energy map, residents are more interested in gross consumption than more sophisticated analyses. Policymakers and energy professionals are more interested in the layered analyses. Energy IT was able to access energy data because Gainesville has a municipal utility and the company had personal relationships with utility employees. Very few people chose to opt-out, so concerns of privacy may be overstated. Data can be messy and difficult to understand. Parcels can have 2 meters, do you add them together or treat them as two different records? Utilities also do predictive billing which means data need to be corrected at times.

Interview	Key Points
Joseph Ferreira Professor of Urban Information Systems DUSP, MIT dusp.mit.edu Data Energy mapping Academic institution	There are many obstacles to correlating utility-provided data with tax assessor records which could provide asset information. There are many-to-many relationships between these databases which complicate understanding what meter correlates with what space and use. Utility address systems do not necessarily match city address systems. Maybe utilities would be interested in definining data taxonomy and structure, that could help bring them to the table.
Bennett Fisher CEO Retroficiency www.retroficiency.com Data Remote assessments Commercial buildings For-profit organization	Having access to granular data facilitates touchless audits. Retroficiency recommends facility upgrades without entering buildings by using 15-minute interval data and in some cases basic building information. Lack of energy data, not lack of technology, is the main obstacle in understanding energy efficiency potential.
Eric Graham Dir. of Energy Efficiency Financing Next Step Living nextstepliving.com Energy mapping Marketing and outreach Residential buildings For-profit organization	An energy map would have limited impact because people would understand how they compare to their neighbors, but not really know what to do. Maps do have the potential to be used for outreach with communities and with individuals. Next Step Living has developed energy "gusher" maps for internal purposes and outreach.
Meghan Shaw Community Outreach Director Cambridge Energy Alliance cambridgeenergyalliance.org Marketing and outreach Multifamily and residential buildings Non-profit organization	Energy data disclosure for residential buildings and smaller buildings would be more burdensome than beneficial - the administrative costs would outweigh information gained. In a low-vacancy market like Cambridge, an energy map will not pressure property owners to improve their buildings. An energy map might help homebuyers make more informed decisions.

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